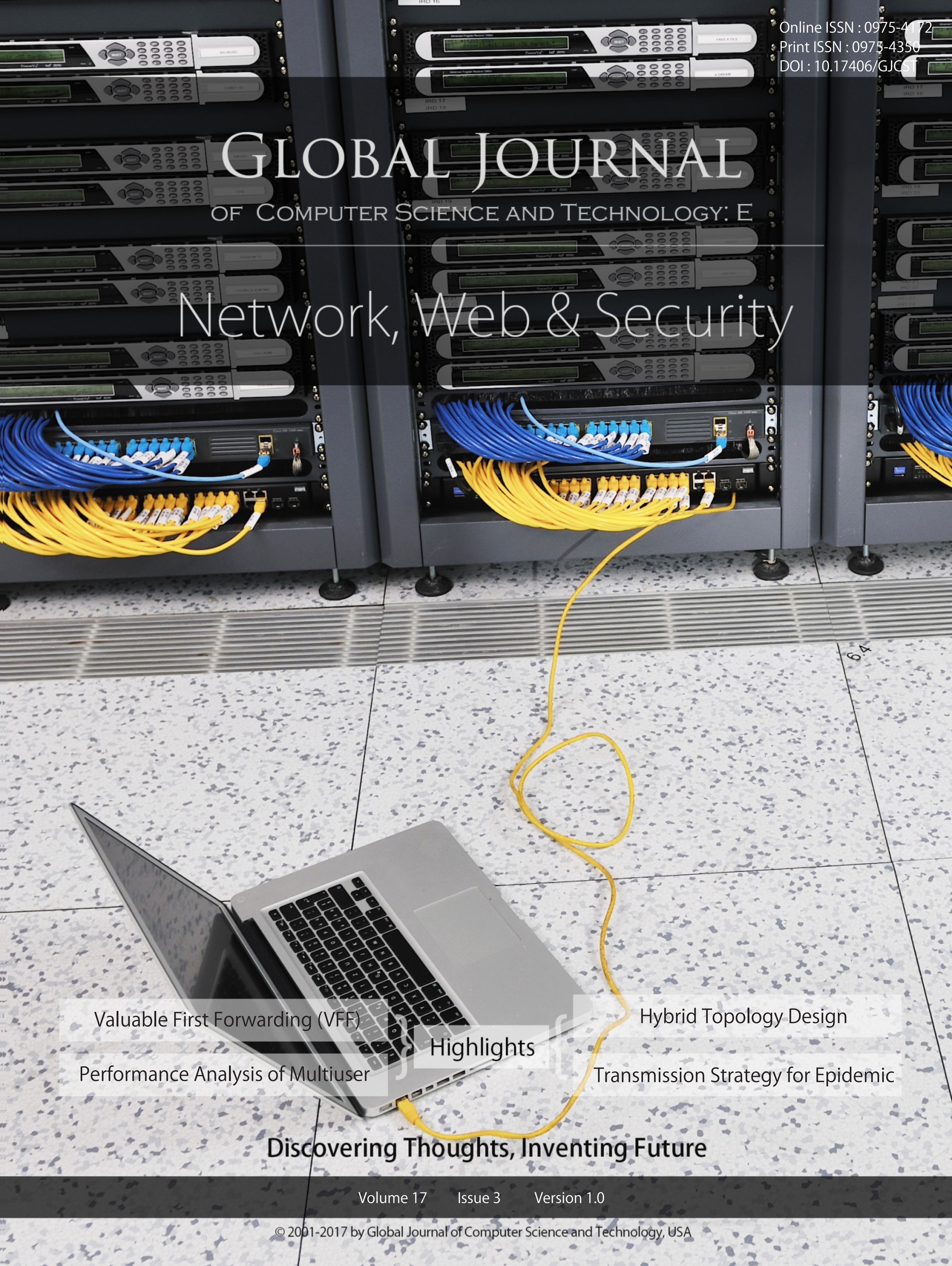

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Valuable First Forwarding (VFF)

Performance Analysis of Multiuser

Highlights

Hybrid Topology Design

Transmission Strategy for Epidemic

Discovering Thoughts, Inventing Future

Volume 17 Issue 3 Version 1.0

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Valuable First Forwarding (VFF) Transmission Strategy for Epidemic Routing in Urban Environments

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Keywords: *delay tolerant network, urban environment, queue management, transmission strategy.*

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VALUABLEFIRSTFORWARDINGVFFTRANSMISSIONSTRATEGYFOREPIDEMICROUTINGINURBANENVIRONMENTS

Strictly as per the compliance and regulations of:

Valuable First Forwarding (VFF) Transmission Strategy for Epidemic Routing in Urban Environments

Wenzao Li [α], Feng Lin [σ], Xi Wu [ρ] & Jiliu Zhou [ω]

Abstract- The message queue mode in sending buffer of mobile node can impact the performance of Delay Tolerant Network (DTN). In urban environment, mobile nodes have a certain community-based movement feature, and which is related to time of day. The queue management of Epidemic routing can be improved in this environment, because some messages of a node are difficult to be transmitted to another community group within short contact time and limited transmission bandwidth. Some packets have not got a transmission opportunity when the Time To Live (TTL) of packets are exhausted. In order to make the messages delivery as much, the queue management in sending buffer becomes an important issue in DTN. The valuable message should be forwarded first, but how to define the value of a message? Therefore, we focus on improving the performance of Epidemic routing in urban environments and Valuable First Forwarding (VFF) transmission strategy in sending buffer is proposed. The TTL and message hops are jointly considered in this strategy, and the simulation results suggest that the VFF outperforms the random, FIFO and optimized MinHop (MH) queue mode in end-to-end path latency, delivery ratio and network overhead ratio.

Keywords: delay tolerant network, urban environment, queue management, transmission strategy.

I. Introduction

Delay Tolerant Network (DTN) is composed of isolated wireless sensors, the transmission path is unstable or changing over time. Routing is difficult in such environment due to the uncertain encounter-chance of mobile nodes. DTN is widely discussed in the challenged networks such as Military areas [1]and Civilian areas [2] . In the DTN architecture, the store-and-forward message routing method is employed to overcome communication disruptions. While the relay node selection methods are still important, a proper queue management needs also to exploit the precious contact opportunity to achieve a better network performance [3].

The movement features of mobile node are different in warier environments, it led to the routing design and queue management is not the same in different environment. With the appearance of smart devices equipped with several of sensors, DTN becomes more viable by using wearable smart devices in urban environment[4, 5]. Therefore, it is necessary to design a more suitable queue management than traditional queue mode in the urban environment. The contact time between two nodes is short in many circumstances, so not all the messages can be forwarded in the limited time period. Focusing on these problems, message order in sending buffer can be adjusted for performance optimized. The impact on the performance of DTN is difficult to determine when the queue mode is random forwarding, which has much randomness. In First In First Out (FIFO) queue management, the oldest will be forwarded first when the contact opportunity comes. The messages in sending buffer are come from one or more nodes in urban environment. Apart from its simplicity and the forwarding behavior don't consider the valuable of each message, this queue management is flawed severely. For example, a valuable message is received by a relay node, and the TTL of this message is running short. If the relay node meets the destination node, this message will miss this opportunity except the message just at the front of the queue. It is very likely that the massage had been aborted before the contact opportunity comes again.

We extend further the MinHop (MH) queue management proposed in [6] with environment consideration and performance enhancements. This paper has three main contributions. First, it presents a new queue management approach using a valuable message first forwarding. Second, we compare the effectiveness of Radom, FIFO, MH and VFF queue mode in urban scenario. The results shows that the VFF queue mode outperforms the Radom, FIFO, and MH in successful delivery ratio, network overhead ratio, and average delay in urban environment. Third, the forwarding approach includes a redundant removing strategy.

The remaining paper is prearranged as below: Section 2 describes the related work of VFF, and Section 3 describes the forwarding and removing strategy of VFF. In section 4, this paper gives the simulation

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parameters and queue mode comparing results, then this paper is concluded in Section 5.

II. Related Works

Urban environments are different from other environments for DTN application, and these differences caused by the nodes' movement. Therefore, traditional queue management approach cannot reach its potential in a particular environment. Generally different DTN applications require different performance indicators. Rodrigo P et al. in [7] proposed a street lighting system, and they focus on the efficient method in energetic terms and latency. In [8], Cardone G et al. put forward a data collection system in a urban environment, this solution require relative high delivery ratio in DTN. Hence, it is necessary for suitable queue management research in urban environment. The sensors are carried by people or fixed in vehicles, and the message transmit behavior only occur during the contact time. So the queue management approach should considerate the characteristic of person's encounter. The message forwarding approach is based on broadcasting in Epidemic routing protocol . With a large sending buffer, Epidemic can achieve a high performance rate [9]. Thus, the manage approach can impact on performance with sufficient buffer in DTN. Furthermore, the message will occupy almost the network resource without massage survival restriction [10]. The TTL mechanism aborts the message after a time period, the unfortunate queue management cause exhausted TTL in waiting transmission.

Generally, to perform an evaluation using social environment in DTN systems, the data trace of mobile sensor, deployment environment and the node's relationship among the participant should be needed [11]. In urban environment, Ekman F et al.[12] shows that the most people goes to work in the morning, spend their day at office for work, and go shopping or return their home in the evening for a familiar way. So, the encounter probability associates with the moment of a day. In urban environment, the most existing queue management approach, such as Random Queue Mode (RND), FIFO, and MH, are don't consider the message survival time and encounter probability. The each mobile node has some social skills to others, to sum up: 1. No motivation, 2. Low motivation, 3. High motivation. The nodes' motivation can be manifested by encounter numbers in urban environment (They are not the only example), and it can be assumed as Tab.1.

Table 1: A Example for Node A's Motivation in a Urban Scenario

Motivation Types	Encounter Times per day
No motivation	0~1
Low motivation	2~4
High motivation	More than 4

The packets should be forwarded by the encounter opportunity. Generally speaking, high motivation nodes are suitable for message carrier, but a meaningless forwarding would waste the TTL and waste an opportunity. Thus, a more suitable queue management for Epidemic routing in urban environment, VFF mode approach with the TTL and hop factors is proposed.

III. Valuable First Forwarding (VFF)Queue Mode

In this section, we introduce the VFF design and the removing strategy for DTN in Urban environment.

a) Transmission Characteristics in Urban Environments

The mobile nodes have social relationship, such as workmates, family, and classmates. The social relations among people can represent as the social graph [13], which is shown in Fig.1.

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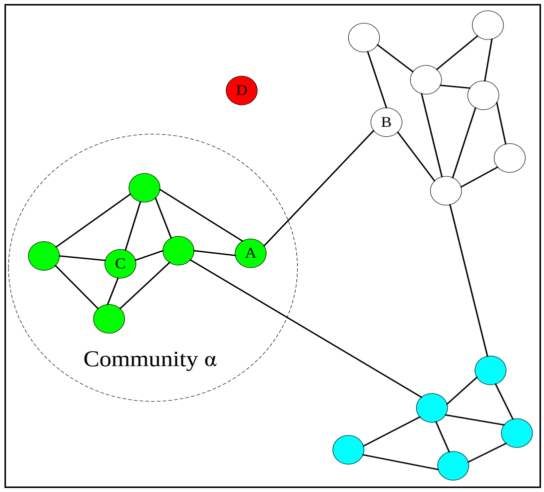


Fig.1: Illustration of community groups in a contact graph. Each color represents one group. The line between two nodes represent that the two nodes have contact relationship

There are many community groups in an urban environment, and some nodes of groups are able to contact other nodes which belong to the other groups. The Fig. 1 shows that, the community α have node A, which have contact with another group. Obviously, the same group nodes have frequent contact. According to Tab.1 for the classification of the nodes' social skill, the node D is No motivation type, the node C belongs to the High motivation type and the node A, node B is Low motivation type. There are many research papers using centrality metric for message forwarding [14, 15]. The contact probability depend on the topology of the contact graph, it cannot be represented the contact probability exactly to other nodes. Thus Gao et al. proposed a weighted social network model[16], The average contact probability between (i,j) is defined as formula 1, which obeys the Poison modeling of social networks.

$$C_i = 1 - \frac{1}{N-1} \sum_{j=1, j \neq i} e^{-\lambda_{ij} T} \tag{1}$$

Where, C_i indicates the average contact probability between node i and node j within time period T. N represents the nodes' number in DTN. This model is suitable in multicast routing environment and it is used for relay node selection. The higher centrality will be selected, such as node C in Fig.1. We assume that ϖ messages in node i could be transmitted in one contact chance with node j, and then a probability ξ_m, that the message m is forwarded, can be represented as (2)

$$\xi_m^{ij} = \frac{\varpi}{\kappa} - \frac{\varpi}{N\kappa - \kappa} \sum_{j=1, j \neq i}^{N} e^{-\lambda_{ij} t} \tag{2}$$

Where the κ represent the messages in the sending buffer of node i. For $\tilde{t} = \{t_1, t_2, \cdots t_\varpi\}$ represent the survival time (TTL) of each message in node i, the $\tilde{t} \in (0,t)$ and the t represents the initial survival time of the message in DTN. Each pair of messages $\{m_{t'}, m_{t''}\}$ can be compared the delivery probability when the survival time meet the condition $(t' < t'')$. Thus, the probability difference equation for $m_{t'}, m_{t''}$ can be written as (3)

$$\xi(t'') - \xi(t') = \frac{\varpi}{\kappa} - \frac{\varpi}{N\kappa - \kappa} \sum_{j=1, j \neq i}^{N} e^{-\lambda_{ij} t''} - \frac{\varpi}{\kappa} + \frac{\varpi}{N\kappa - \kappa} \sum_{j=1, j \neq i}^{N} e^{-\lambda_{ij} t'}$$

$$= \frac{\varpi}{\kappa(N-1)} \sum_{j=1, j \neq i}^{N} \left(e^{-\lambda_{ij} t'} - e^{-\lambda_{ij} t''}\right) \tag{3}$$

The $e^{-\lambda_{ij} t}$ is monotonically decreasing function when contact rate $\lambda_{ij} > 0$. Obviously, $\xi(t'') - \xi(t') > 0$. So the higher TTL value has a larger delivery probability in urban environment.

In urban environment, we start by classifying people motivation in three groups as Tab1. If some people are classmates or colleagues, they will repeat contact with limited range for longer time scales. These frequent contacts will cause some messages with relative higher hops number. Assuming that a message is forwarded many hops in the time point $t_1, t_2 \cdots t_n$, the probability density functions of $t_1, t_2 \cdots t_n$ are $f(t_1), f(t_2) \cdots f(t_n)$. $P(t_1 + t_2 + \cdots + t_n)$ can calculated through the convolution as Equation 4.

$$\mathrm{P}(t_1 + t_2 + \cdots + t_n) = \int_0^t f(t_1) \otimes f(t_2) \otimes \cdots \otimes f(t_n) dt \quad (4)$$

The condition $\mathrm{P}' > \mathrm{P}''$ is satisfied when $\mathrm{K} > M$, where the P'' represents the probability after K hops and the P' represents the probability after M hops. There are many repeat contact nodes in same group which it is frequent appearance in a narrow area, which is considered as a community in urban environment.

b) VFF Queue Management and Removing Strategy

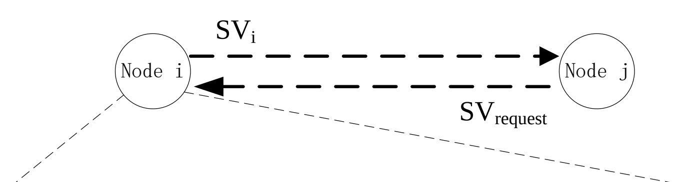
The messages are forward to other nodes which belong to the same community, we think this delivery behavior is insignificance. On the contrary, The No motivation or Low motivation type nodes, (e.g. node D or node A in Fig.1) which have less transmission opportunity, they should have some valuable messages to broadcast. The valuable behavior should broadcast messages to extensive regions in limited time. So we propose a method to measure the transmission value, in which the valuable message should be forwarded first. The forward processes are shown as blew:

Step 1: The message is added a field χ to record the hop times in the frame structure. The χ plus one when the message is forwarded once.

Step 2: When a contact opportunity occurs, then the messages will be rearranged by value calculation in sending buffer. It is calculated by Equation (5)

$$\psi_i = \alpha \frac{\tilde{t}_i}{\chi_i} \quad (5)$$

The Epidemic with VFF forwarding order is shown as the Fig. 2.



	Value	TTL remaining	Hops	Forwarding order
M1	7.33	22s	3	2
M2	22.5	45s	2	1
M3	5.14	36s	7	3
M4	3.84	50s	13	4

Fig.2: The forwarding order generated by calculation when the node i has a transmission opportunity

In Epidemic routing algorithm, The parties must exchange summery vectors (SV). After node j receives the SV_i which is represents the message summery vector of node i then node j will send the $SV_{request}$ to node i and $SV_{request}$ means that those messages not do not exist in sending buffer of node j. The $SV_{request}$ between node i and node j can calculate as Equation (6)[9]

$$SV_{request}^{ij} = \sum_{m=1}^{\mathcal{L}} M_m^j - \sum_{m=1}^{\mathcal{L}'} M_m^i \quad (6)$$

Then the message sending order by node i is shown as Fig.3

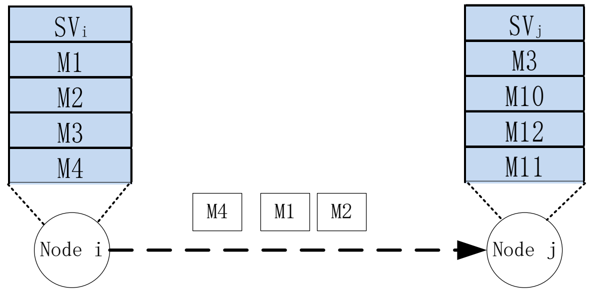


Fig.2: The forwarding order after summery vectors are exchanged between two nodes

Step 3: Removing redundant messages strategy: Each node builds a list T, it records those messages which already successful delivered to destination. When to nodes has a transmission opportunity they will exchange the T first. Then the two sides calculate the T by Equation (7).

$$\bar{T}_i = \complement_{T_i \cap T_j} T_i \tag{7}$$

Where the $\bar{T}_i$ represents the complement set between set T_i and set $T_i \cap T_j$. It means that the record of $\bar{T}_i$ are successful delivery messages which does not exist in T_i before. Then the node i will delete the messages in sending buffer if it is exist in $\bar{T}_i$. When the update of list T is completed, the new list T' is set $(T_i \cap T_j)$.

Because there is no strategy on redundant message control in Epidemic routing, and the intermediate state nodes still forward the redundant messages. Obviously, the removing strategy can decrease the network overhead ratio in DTN.

IV. Simulation and Results

In this section, the simulation environment, key parameters and the simulation results are introduced. In order to verify the performance of VFF queue management strategy, it is compared with other queue management methods:

1. Random: The message in sending buffer will be random selected to transmission to neighbor node.
2. FIFO: In this mode, all messages are arranged according to in coming arrival time. When transmission opportunity appears, the oldest messages will be transmitted first.
3. MH: The hops number will be recorded in the sending buffer. When forwarding opportunity arises, the minimal hops message will be transmitted first [6].

We observed several key indicators from two aspects, the indicators change with the increased node density and buffer size.

a) Simulation Environment

Frans et al. propose a movement model named Working Day Movement (WDM) Model [12], and it shows that average person goes to work in the morning, spends their day in office, and goes shopping or returns their home in the evening. Furthermore, the encounter features is associated with daily routines of people. This movement feature model accords with the realistic situation. For this purpose, we set three types mobile nodes in the simulation scenario, it includes pedestrian node, buses node and taxies node. We had ranging from 70-270 mobile nodes moving on a map of Helsinki centre area. These nodes move regularly to position of home, offices and shops, which is controlled by the WKT data files, which is provided by The Opportunistic Network Environment simulator (The ONE) [17]. All mobile nodes are restricted in a rectangular (10000m*8000m). There are two types interface in the simulation, one is low speed interface with 100kbps and 10m transmitting range, another is high speed interface with 10Mbps and 100m transmitting range, and they are equipped in buses and taxies. The other details about the assignments of nodes are listed in Tab.2.

Table 2: The assignment of nodes, interfaces and positions to the different groups

Groups	Type	Nodes	Interface
A ,B,C,D,E	Pedestrian	10~50 for each	1
o,p,q,r,s	Bus	2 for each	2
T	Taxi	10	2

The simulation time is set 12 hours, which can show the movement regular during the day. We observed the message interaction process, it partly indicates the motivation level in urban environment and it is shown as Fig.3.

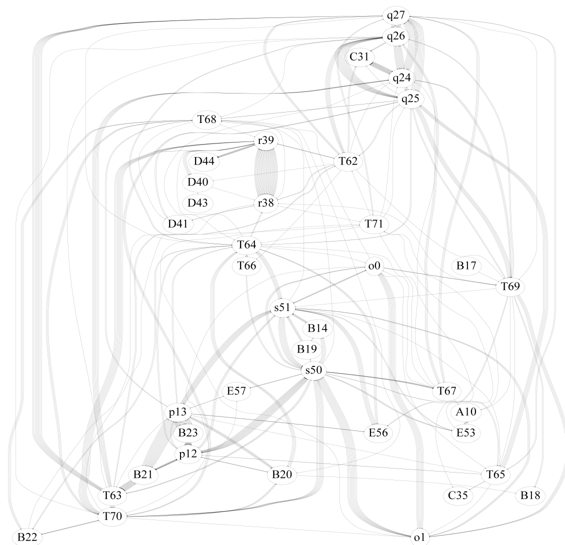


Fig.3: The packets passing process in a urban scenario (with help from Graphviz)

As it is shown in Fig.3, node B14 and node B19 are frequent communication. We think the value of their most messages are low in Epidemic routing, it should be set to lower priority in queue mode. In addition, it meets our assumptions about the node social skills classification. Some nodes contact frequently, some nodes are not so active, and some nodes imply transmission inertia.

We set a urban scenario as real as possible in order to verify the effectiveness of the VFF approach, and we ran the simulations for each queue mode several times under the same scenario and parameter setting using the ONE simulator:(Tab.3)

Table 3: Key simulation parameters

Parameter	Value
World Size	10000m*8000m
Simulation Time	43200 seconds
City Scenario	Helsinki
Buffer Size	4M~20M
Message TTL	400 seconds
Message Size	50k,100k
Movement Model	WDM(Pedestrian), Bus Movement(Bus), ShortestPathMapBasedMovement(Taxi)

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To validate that the VFF outperforms the existing the queue mode Random, FIFO and MH in urban environments, we use the following three metrics: successful delivery rate, network overhead ratio and average delivery latency. Moreover, we observed the change of node density and buffer size impact on performance.

b) Successful delivery ratio

The delivery ratio is the ratio of the successful delivered to the destination within given time period, and it is an important indicator for DTNs.

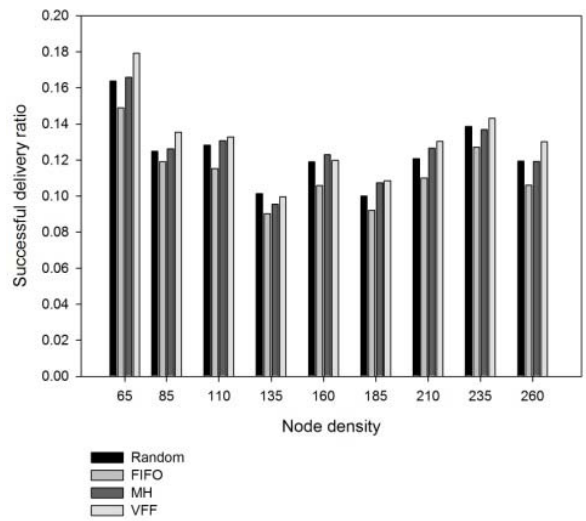

Fig.4: Comparisons of successful delivery ratio under the increasing node density

From Fig.4, the result shows that FIFO queue mode performs worse in this scenario, and the Random queue mode has certain uncertainty. VFF approach had a better delivery ratio than others except under 135 nodes and 160 nodes scenario. Upon the whole, VFF is superior to the Random, FIFO and MH in urban environments.

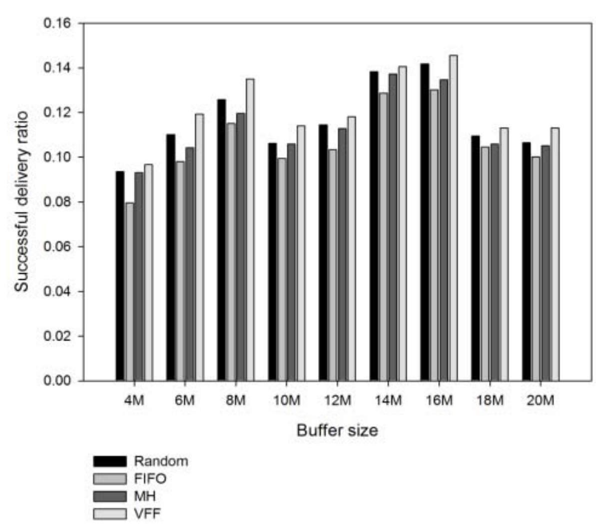

Fig.5: Comparisons successful delivery ratio under the increasing sending-buffer size

VFF is better than the other queue mode with different node buffer size (Fig.5). Likewise, the FIFO has poor performance of delivery ratio. FIFO is influenced by the mechanic, and ossified handling way in urban environments.

c) Network overhead ratio

The network overhead ratio can reflect the network load to some extent. The lower value of overhead ratio indicates the better delivery efficiency. The overhead ratio δ is defined as Equation (8).

$$\delta = \frac{\sum_0^t \varphi - \sum_0^t \omega}{\sum_0^t \omega} \quad (8)$$

Where φ represents the successful transmitting times, and ω is successful delivery times.

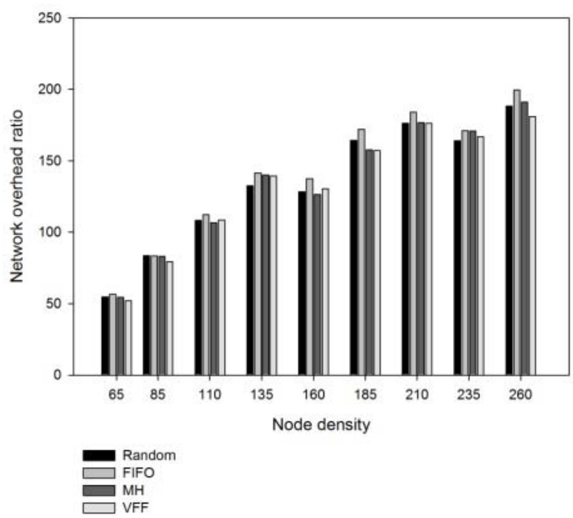

Fig.6: Comparisons of network overhead ratio under the increasing node density

Fig.6 shows that VFF does not have an absolute advantage in different density with the overhead ratio. This result is caused by the uneven node density. Despite such randomness interference exists, VFF general superior to others, and it is acceptable in DTNs.

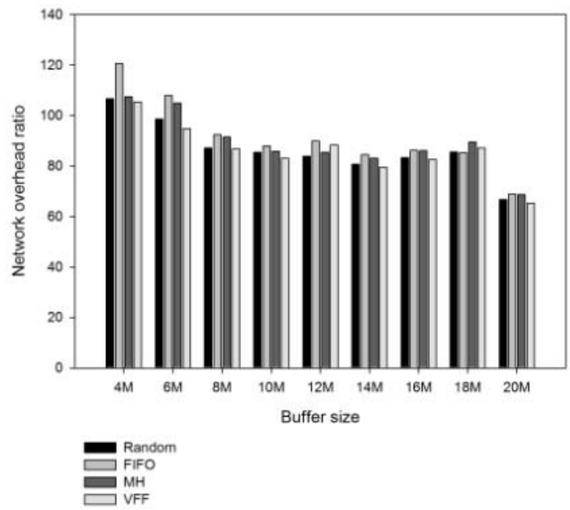

Fig.7: Comparisons of network overhead ratio under the increasing sending-buffer size

Likewise, the performance of VFF strategy is not significantly better than other methods in different buffer size. VFF approach is clearly better than FIFO and MH at low buffer size area (4M~10M). Network overhead ratio shows decreasing trend with the increasing sending buffer, and it represents the DTN delivery efficiency. Each queue management method result in smaller gaps of overhead ratio and delivery ratio, this is due to the limited impact of queue management in Epidemic algorithm.

d) Average latency

Average latency is the average time with message time consumption during source-to-destination path. The source-to-destination average latency is desired for short value in DTN design.

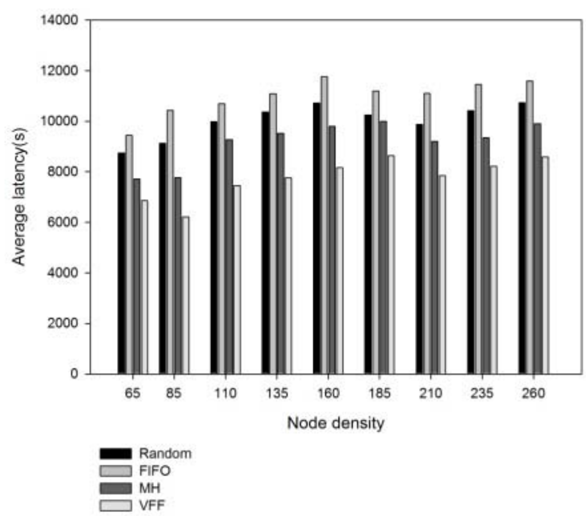

Fig.8: Average latency under the node density increasing

It is clear that in Epidemic routing, VFF queue management is superior to other methods at deferent node density (Fig.8). Because these queue modes are in the same urban scenario, the VFF's lower value of average latency and higher value delivery ratio suggest that VFF selects the more correct messages to transmit first than the others.

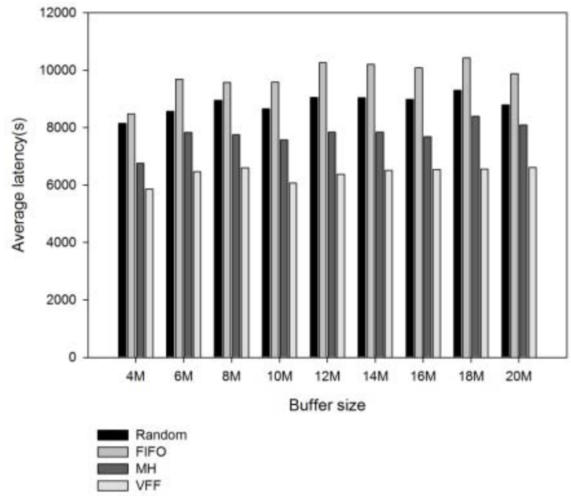

Fig.8: Average latency under the sending-buffer size increasing

Moreover, we observe the average latency at different sending buffer size, VFF still show up better performance than other queue mode.

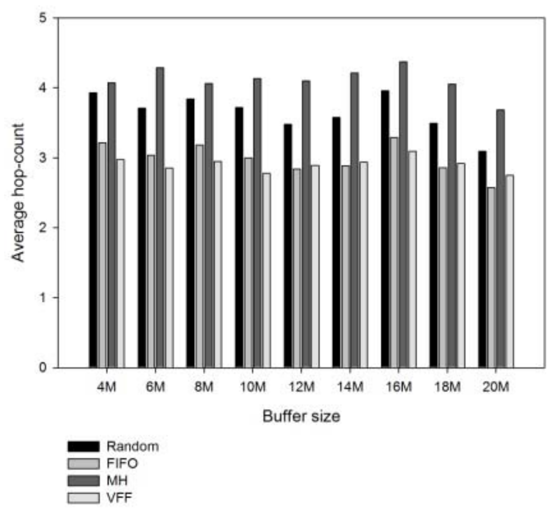

Fig.9: Average hop-count under the sending-buffer size increasing

From Fig.9, VFF has certain advantages on average hops. The message average hop-count represents the messages forwarded status around the network, and the higher value of hop-number reflects that the message is forwarding frequently. Assuming under the same delivery ratio, the smaller hop-number showed more efficient forwarding behavior for messages.

V. Conclusion and Prospects

The suitable queue mode strategy for Epidemic routing in urban environment is currently, one of the valuable topics in DTN design. In this paper, we propose a forwarding strategy named VFF that optimizes the Epidemic routing in urban environment. The nodes movement feature and social character are jointly considered in this proposed queue management strategy. In such challenging network environment, the most valuable messages should be forwarded fist on the precious encounter chance. There will be more and more DTN applications in urban environment with the increasing low price of smart devices and sensors, such optimized strategy conducive to DTN application design. In future research work with the queue management, we would focus on the message valuable function design, which can get better performance with Epidemic routing in urban environment.

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Performance Analysis of Multiuser Downlink MIMO NOMA Wireless Communication System on Color Image Transmission

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Abstract- In this paper, a comprehensive study has been made to evaluate the performance of 2 × 2 multiantenna configured MIMO NOMA wireless communication system. The simulated system incorporatesvarious types of signal processing techniques (Channel coding: LDPC & Convolutional, Digital modulation: QPSK, DQPSK & 4-QAM, Signal detection: ML decoding based QR channel decomposition aided SIC). On considering downlink transmission of encrypted color image of each of two users in a hostile fading channel, it is noticeable from MATLAB based simulation study that the system is very much robust and effective in retrieving transmitted color images underutilization of LDPC channel coding and 4-QAM digital modulation techniques. The performance of the simulated downlink MIMO NOMA wireless communication system has been evaluated in terms of bite error rate(BER) under scenario of various receive signal to noise ratio(SNR) ranging from 0dB to 16dB.

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GJCST-E Classification: C.2.1

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Strictly as per the compliance and regulations of:

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Md. Humaun Kabir [α] & Shaikh Enayet Ullah [σ]

Abstract- In this paper, a comprehensive study has been made to evaluate the performance of 2 × 2 multiantenna configured MIMO NOMA wireless communication system. The simulated system incorporates various types of signal processing techniques (Channel coding: LDPC & Convolutional, Digital modulation: QPSK, DQPSK & 4-QAM, Signal detection: ML decoding based QR channel decomposition aided SIC). On considering downlink transmission of encrypted color image of each of two users in a hostile fading channel, it is noticeable from MATLAB based simulation study that the system is very much robust and effective in retrieving transmitted color images under utilization of LDPC channel coding and 4-QAM digital modulation techniques. The performance of the simulated downlink MIMO NOMA wireless communication system has been evaluated in terms of bit error rate(BER) under scenario of various receive signal to noise ratio(SNR) ranging from 0dB to 16dB.

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I. Introduction

With rapid technological advancement in both mobile and wireless communications, the number of users for affordable and powerful mobile computing devices (smartphones, iPhones, netbooks, and laptops) is increasing and leading an exponential increase in the amount of data traffic that the network operators need to accommodate within their networks. It is expected that by 2020 the global IP network will carry 6.4 EB of Internet traffic per day and 21 GB per capita. In perspective of coping with this explosion of broadband data traffic, the network operators will make use of various new solutions and technologies to be integrated for network capacity enhancement in the next generation/5G mobile networks. Some of the promising solutions include the deployment of heterogeneous small cell networks which enables dynamic cooperation between different radio access technologies, MIMO/Massive MIMO(using a large number of antennas, 100 or more)for simultaneous serving a number of users in the same time frequency resource; Cloud radio access networks (C-RAN) offering a centralized, cooperative, clean and cloud computing architecture; Software-defined networks (SDN) and network function virtualization (NFV) that assist the mobile operators to reduce their capital expenditure (CAPEX) intensity by transferring their hardware-based network to software- and cloud based solutions. In view of increasing the spectral efficiency of the next generation/ 5G networks and reduction of inter cell interference levels, another promising solution can accepted to use non-orthogonal multiple access (NOMA) technique[1] . In consideration of supporting higher throughput transmission in next generation (5G) networks, there is a growing interest among the mobile operators to exploit vast amounts of available frequency spectrum in the mmwave band (30-300 GHz).The Non-orthogonal multiple access (NOMA), millimeter wave (mmWave), and massive multiple-input-multiple-output (MIMO) have been emerging as key technologies for the fifth generation (5G) mobile communications [2, 3].

II. Literature Review

It is known from literature reviewing that many researchers of academic institutions and industries have been working since 2014 on suitability of NOMA as 5G compatible radio interface technology based on power-domain user multiplexing scheme. In this paper, few works are described briefly.

In [4],Chenet. al. proved that NOMA combined with SU-MIMO techniques achieved system performance improvement. The impact of rank optimization on the performance of NOMA with SU-MIMO in downlink were studied and 23% for cell average throughput and 33% for cell-edge user throughput were achieved as compared to other orthogonal access system. In [5], Lan et. al. investigated the system-level throughput of NOMA with closed-loop single-user multiple-input multiple-output (SU-MIMO) in the cellular downlink and clarified the potential gains as compared to OMA. In [6] Liu et. al. studied the NOMA based downlink multi-user beamforming system, where the base station (BS) tried to transmit information to multiple user clusters and each beam served one user cluster compromising of two users simultaneously. User

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selection algorithm was proposed to reduce the interference and improved the system information rate. The user power schedule scheme to guarantee the advantage of the proposed NOMA downlink multi-user beam forming system was also proposed in such study. In [7] Shahab et. al. proposed a novel power allocation strategy that can optimize the system ergodic sum capacity while minimizing the mutual interference between the paired users. It was shown through simulations that the proposed scheme outperformed conventional power allocation in terms of bit error rates at the user ends with negligible effect on the system ergodic sum capacity. In [8],Liu and Wang made an investigation on efficient antenna selection and user scheduling algorithms to maximize the sum rate in two MIMO-NOMA scenarios. The authors showed that the proposed antenna selection algorithm achieved near-optimal performance and joint AU contribution algorithm achieved similar performance to existing methods with reduced complexity. In [9], Zhang et. al. made investigative study on the capacity performance of NOMA-mmWave-massive-MIMO systems in noise-dominated low-SNR regime and the interference-dominated high-SNR regime. In [10], Chen and Dai made investigation on designing MED precoders for 2 user 2 × 2 downlink MIMO NOMA system through combination of previously developed methodology of MED precoding under scenarios of unicast MIMO and multicast MIMO. In [11],Zeng et.al. made comparative study on the performance of non-orthogonal multiple access (NOMA) with conventional orthogonal multiple access (OMA) under multiple-input multiple-output (MIMO) channels. The authors showed that MIMO-NOMA dominated MIMO-OMA interms of both sum rate and ergodic sum rate.

III. Signal Processing

In our present study various signal processing schemes have been used. A brief overview of these schemes is given below:

a) Convolutional Channel Coding

In Convolutional channel coding, three parameters, n, k and m(n= number of output bits; k= number of input bits and m= number of memory registers)are used to specify Convolutional codes. The quantity k/n is called the code rate and it is a measure of the efficiency of the code. In this present study, ½ rated convolutional encoders have been used so that the decoding can be performed in some structured and simplified way based on Viterbi decoding algorithm. The constraint length, L= (k (m-1)) represents the number of bits in the encoder memory that affects the generation of then output bits. With consideration of a constraint length of 7and code generator polynomials of 171 and 133 in octal numbering system, the code generator polynomials G1 and G2 can be written as [12]

G1= x0+x2+ x3+x5+ x6=1 0 1 1 0 1 1 =133 (1)
G2= x0+x1+ x2+x3+ x6=1 1 1 1 0 0 1 =171

b) LDPC Channel Coding

In 1960, Robert Gallager invented Low density parity check (LDPC) codes. The LDPC code is a linear error correction code that has a parity check matrix H, which is sparse, i.e., with less nonzero elements in each row and column. In our considered, ½ -rated irregular LDPC code with random distribution of nonzero elements within the column of its parity check matrix [H]. The parity check matrix [H] has a dimension of 64 × 128 formed from a concatenation of two 64× 64 sized matrices [A] and [P]. The columns of the parity-check matrix [H] are rearranged to produce a new parity-check matrix, $\overleftrightarrow{H}$. With rearranged matrix elements of $\overleftrightarrow{H}$, the matrix [A] becomes non-singular and it is further processed to undergo LU decomposition. The parity bits sequence [p] is produced from a block based input binary data sequence [u] = $[u_1\ u_2\ u_3\ u_4 \ldots\ldots u_{64}]^T$and three matrices [P] (of [$\overleftrightarrow{H}$]), [L] and [U] using the following MATLAB notation:

p = mod (**U**\ (**L**\ **z**), 2); where**, z** = mod (**P*****u**, 2). (2)

The LDPC encoded 128× 1 sized block based binary data sequence [**c**] is formulated from concatenation of parity check bit **p** and information bit **u** as: [**c**] = [**p**; **u**]**.** The first 64 bits of the codeword matrix [**c**] are the parity bits and the last 64 bits are the information bits. In iterative Log Domain Sum-Product LDPC decoding algorithm, the transmitted bits are retrieved [13, 14].

c) Signal Detection Scheme for MIMO NOMA Systems

In this subsection, we have tried to provide comprehensive mathematical formulations for ML decoding based QR channel factorization aided SIC scheme implementation based on the works presented in [15]. We assume a layered transmission scenario with two user ($\mathrm{UE_1}$ and $\mathrm{UE_2}$) case for downlink 2x2 MIMO-NOMA system, where $\mathrm{UE_1}$a cell-center user (near user) and $\mathrm{UE_2}$ is a cell-edge user (far user).The base station is equipped with two transmitting antennas and each individual user is equipped with two receiving antennas. The transmitted signal $\mathbf{X}$ is formed from summing up of simultaneous transmission of two spatially multiplexed consecutive complex symbols of each user in one time slot and can be written as:

$$\boldsymbol{X} = (\boldsymbol{X}_1 + \boldsymbol{X}_2) = \left[\binom{x_{1,1}}{x_{1,2}} + \binom{x_{2,1}}{x_{2,2}}\right]$$

$$\Rightarrow \boldsymbol{X} = \sqrt{P_1}\boldsymbol{S}_1 + \sqrt{P_2}\boldsymbol{S}_2 = \left[\sqrt{P_1}\binom{s_{1,1}}{s_{1,2}} + \sqrt{P_2}\binom{s_{2,1}}{s_{2,2}}\right] \quad (3)$$

where, $\mathbf{S}_1$ and $\mathbf{S}_2$ are the transmitted signals of unitary power for $\mathrm{UE_1}$ and $\mathrm{UE_2}$ prior to power allocation, signal components $x_{1,1}$of $UE_1$and $x_{2,1}$of UE_2 are transmitted from first transmitting antenna and $x_{1,2}$ of $UE_1$and $x_{2,2}$ of UE_2 are transmitted from second transmitting antenna. Each of two components of both $\mathbf{S}_1$ and $\mathbf{S}_2$ are needed in power scaling.The 20% of the total power P($P_1 = 0.2$ P)remaining 80% of the total power P($P_2 = 0.8$ P)are allocated to user UE_1 and to user UE_2 respectively. With consideration of 2×2 sized matrices,$[\boldsymbol{H}_1]$ and $[\boldsymbol{H}_2]$ containing complex Rayleigh fading channel coefficients for users UE_1 and UE_2,the received signals at $UE_1(=\mathbf{Y}_1)$ and $UE_2(=\mathbf{Y}_2)$ are given by:

$$\mathbf{Y}_1=\mathbf{H}_1(\mathbf{X}_1+\mathbf{X}_2)+\mathbf{n}_1 \quad (4)$$

$$\mathbf{Y}_2=\mathbf{H}_2(\mathbf{X}_1+\mathbf{X}_2)+\mathbf{n}_2 \quad (5)$$

where $\boldsymbol{n}_1$ and $\mathbf{n}_2$are the additive white Gaussian noises (AWGN) estimated based on the typically assumed receive SNR values at receivers of user UE_1 and user UE_2respectively.

In case of estimating transmitted signals for user UE_1, equation(4) can be written in elaborate form as:

$$\boldsymbol{Y}_1=\begin{bmatrix}Y_{11}\\Y_{12}\end{bmatrix}=\begin{bmatrix}H_1(1,1) & H_1(1,2)\\H_1(2,1) & H_1(2,2)\end{bmatrix}\left[\begin{pmatrix}X_{1,1}\\X_{1,2}\end{pmatrix}+\begin{pmatrix}X_{2,1}\\X_{2,2}\end{pmatrix}\right]+\begin{bmatrix}n_{1,1}\\n_{1,2}\end{bmatrix} \quad (6)$$

The signal received at first layer of user UE_1 is given by

$$Y_{11}=H_1(1,1)(X_{1,1}+X_{2,1})+H_1(1,2)(X_{1,2}+X_{2,2})+n_{1,1} \quad (7)$$

The signal received at second layer of userUE_1 is given by

$$Y_{12}=H_1(2,1)(X_{1,1}+X_{2,1})+H_1(2,2)(X_{1,2}+X_{2,2})+n_{1,2} \quad (8)$$

On performing QR matrix decomposition of $\mathbf{H}_1$as:

$$\mathbf{H}_1=\mathbf{Q}_1\mathbf{R}_1 \quad (9)$$

where,$\mathbf{Q}_1$is a 2 × 2 unitary matrix and $\mathbf{R}_1$is an 2 × 2 upper triangular matrix and multiplying both sides of equation(6) with complex conjugate transformed of $\mathbf{Q}_1$, we get: .

$$\boldsymbol{Z}_1=\boldsymbol{Q}_1^H\boldsymbol{Y}_1=\boldsymbol{R}_1(\boldsymbol{X}_1+\boldsymbol{X}_2)+\boldsymbol{n}_1$$

$$=\begin{bmatrix}R_1(1,1) & R_1(1,2)\\0 & R_1(2,2)\end{bmatrix}\left[\begin{pmatrix}X_{1,1}\\X_{1,2}\end{pmatrix}+\begin{pmatrix}X_{2,1}\\X_{2,2}\end{pmatrix}\right]+\begin{bmatrix}n_{1,1}\\n_{1,2}\end{bmatrix}$$

$$\Rightarrow\begin{bmatrix}Z_{1,1}\\Z_{1,2}\end{bmatrix}=\begin{bmatrix}R_1(1,1) & R_1(1,2)\\0 & R_1(2,2)\end{bmatrix}\left[\begin{pmatrix}X_{1,1}\\X_{1,2}\end{pmatrix}+\begin{pmatrix}X_{2,1}\\X_{2,2}\end{pmatrix}\right]+\begin{bmatrix}n_{1,1}\\n_{1,2}\end{bmatrix} \quad (10)$$

From equation (10), the components of $\boldsymbol{Z}_1(Z_{1,1}$and $Z_{1,2})$ can be written as:

$$Z_{1,1}=R_1(1,1)(X_{1,1}+X_{2,1})+R_1(1,2)\,(X_{1,2}+X_{2,2})+n_{1,1} \quad (11)$$

$$Z_{1,2}=R_1(2,2)(X_{1,2}+X_{2,2})+n_{1,2} \quad (12)$$

Neglecting contribution from noise in equation (12) and the estimated transmitted symbols for both users can be written as

$$(X_{1,2}+X_{2,2})=\frac{Z_{1,2}}{R_1(2,2)} \quad (13)$$

Substituting the value of $(X_{1,2}+X_{2,2})$from equation (13) in equation (11) and neglecting the noise component, we can write

$$Z_{1,1}=R_1(1,1)(X_{1,1}+X_{2,1})+R_1(1,2)\frac{Z_{1,2}}{R_1(2,2)} \quad (14)$$

$$(X_{1,1}+X_{2,1})=\frac{Z_{1,1}}{R_1(1,1)}-\frac{R_1(1,2)}{R_1(1,1)}\frac{Z_{1,2}}{R_1(2,2)} \quad (15)$$

The right hand term of equation (15) is known and this equation can be written in modified form as

$$\hat{Z}_{1,1}=\frac{Z_{1,1}}{R_1(1,1)}-\frac{R_1(1,2)}{R_1(1,1)}\frac{Z_{1,2}}{R_1(2,2)}$$

$$=(X_{1,1}+X_{2,1})=\sqrt{P_1}\boldsymbol{S}_{1,1}+\sqrt{P_2}\boldsymbol{S}_{2,1} \quad (16)$$

Dividing equation (16) by $\sqrt{P_1}$, we get

$$\hat{\hat{Z}}_{1,1}=\boldsymbol{S}_{1,1}+\sqrt{\frac{P_2}{P_1}}\boldsymbol{S}_{2,1}=\boldsymbol{S}_{1,1}+2.0\,\mathbf{S}_{2,1} \quad (17)$$

As the modulated symbols are normalized in such that each complex symbols has unitary power. The normalized QAM modulated signal vector is denoted by $\underline{\mathbf{S}}$. Then the transmitted symbol from first transmitting antenna considered as interference component for UE_1can be estimated using ML decoding based QR channel decomposition aided SIC scheme as

$$\widehat{\boldsymbol{S}}_{2,1}=\arg\min\left\|\hat{\hat{Z}}_{1,1}-2.0\,\widehat{\boldsymbol{S}}\right\|^2 \quad (18)$$

where, $\widehat{\boldsymbol{S}}\in\underline{\boldsymbol{S}}$ and $\|.\|^2$ is indicative of Frobenius norm of matrix. Equation(13) can be written in modified form as:

$$\frac{Z_{1,2}}{R_1(2,2)}=\sqrt{P_1}\boldsymbol{S}_{1,2}+\sqrt{P_2}\boldsymbol{S}_{2,2} \quad (19)$$

Dividing equation (19)by $\sqrt{P_1}$, we get

$$\frac{Z_{1,2}}{\sqrt{P_1}\,R_1(2,2)}=\boldsymbol{S}_{1,2}+\sqrt{\frac{P_2}{P_1}}\boldsymbol{S}_{2,2}$$

$$\hat{Z}_{1,2}=\frac{Z_{1,2}}{\sqrt{P_1}\,R_1(2,2)}=\boldsymbol{S}_{1,2}+2.0\,\boldsymbol{S}_{2,2} \quad (20)$$

The transmitted symbol from second transmitting antenna for considered as interference component for UE_1can be estimated using ML decoding based QR channel decomposition aided SICscheme as

$$\widehat{\boldsymbol{S}}_{2,2}=\arg\min\left\|\hat{Z}_{1,2}-2.0\,\widehat{\boldsymbol{S}}\right\|^2 \quad (21)$$

where $\widehat{\boldsymbol{S}}\in\underline{\boldsymbol{S}}$ and $\|.\|^2$ have already been specified.

Substituting the value of $\widehat{\boldsymbol{S}}_{2,2}$ in equation (20), the transmitted symbol from second transmitting antenna for user UE_1as desired signal component can be estimated as:

$$\widehat{\boldsymbol{S}}_{1,2}=\hat{Z}_{1,2}\text{-}2.0\,\widehat{\boldsymbol{S}}_{2,2} \quad (22)$$

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Substituting the value of $\widehat{\boldsymbol{S}}_{2,1}$ from equation (18) in equation (17),the transmitted symbol from first transmitting antenna for user UE_1as desired signal component can be estimated as:

$$\widehat{\boldsymbol{S}}_{1,1}=\hat{\hat{Z}}_{1,1}-2.0\,\widehat{\boldsymbol{S}}_{2,1} \quad (23)$$

In case of estimating transmitted signals for userUE_2, equation(5) can be written in elaborate form as:

$$\boldsymbol{Y}_2=\begin{bmatrix}Y_{21}\\ Y_{22}\end{bmatrix}=\begin{bmatrix}H_2(1,1) & H_2(1,2)\\ H_2(2,1) & H_2(2,2)\end{bmatrix}\left[\begin{pmatrix}X_{1,1}\\ X_{1,2}\end{pmatrix}+\begin{pmatrix}X_{2,1}\\ X_{2,2}\end{pmatrix}\right]+\begin{bmatrix}n_{2,1}\\ n_{2,2}\end{bmatrix} \quad (24)$$

The signal received at first layer of user UE_2 is given by

$$Y_{21}=H_2(1,1)(X_{1,1}+X_{2,1})+H_2(1,2)(X_{1,2}+X_{2,2})+n_{2,1} \quad (25)$$

The signal received at second layer of user UE_2 is given by

$$Y_{22}=H_2(2,1)(X_{1,1}+X_{2,1})+H_2(2,2)(X_{1,2}+X_{2,2})+n_{2,2} \quad (26)$$

On performing QR matrix decomposition of $\mathbf{H}_2$as:

$$\mathbf{H}_2=\mathbf{Q}_2\mathbf{R}_2 \quad (27)$$

where,$\mathbf{Q}_2$isa 2×2 unitary matrix and $\mathbf{R}_2$is an 2×2 upper triangular matrix and multiplying both sides of equation (24) with complex conjugate transformed of $\mathbf{Q}_2$, we get: .

$$\boldsymbol{Z}_2=\boldsymbol{Q}_2^H\boldsymbol{Y}_2=\boldsymbol{R}_2(\boldsymbol{X}_1+\boldsymbol{X}_2)+\boldsymbol{n}_2$$

$$=\begin{bmatrix}R_2(1,1) & R_2(1,2)\\ 0 & R_2(2,2)\end{bmatrix}\left[\begin{pmatrix}X_{1,1}\\ X_{1,2}\end{pmatrix}+\begin{pmatrix}X_{2,1}\\ X_{2,2}\end{pmatrix}\right]+\begin{bmatrix}n_{2,1}\\ n_{2,,2}\end{bmatrix}$$

$$\Rightarrow\begin{bmatrix}Z_{2,1}\\ Z_{2,2}\end{bmatrix}=\begin{bmatrix}R_2(1,1) & R_2(1,2)\\ 0 & R_2(2,2)\end{bmatrix}\left[\begin{pmatrix}X_{1,1}\\ X_{1,2}\end{pmatrix}+\begin{pmatrix}X_{2,1}\\ X_{2,2}\end{pmatrix}\right]+\begin{bmatrix}n_{2,1}\\ n_{2,2}\end{bmatrix} \quad (28)$$

From equation (28), the components of $\boldsymbol{Z}_2(Z_{2,1}$and $Z_{2,2})$ can be written as:

$$Z_{2,1}=R_2(1,1)(X_{1,1}+X_{2,1})+R_2(1,2)\,(X_{1,2}+X_{2,2})+n_{2,1} \quad (29)$$

$$Z_{2,2}=R_2(2,2)(X_{1,2}+X_{2,2})+n_{2,2} \quad (30)$$

Neglecting contribution from noise in equation (30) and the estimated transmitted symbols for both users can be written as

$$(X_{1,2}+X_{2,2})=\frac{Z_{2,2}}{R_2(2,2)} \quad (31)$$

Substituting the value of $(X_{1,2}+X_{2,2})$from equation (31) in equation (29) and neglecting the noise component, we can write

$$Z_{2,1}=R_2(1,1)(X_{1,1}+X_{2,1})+R_2(1,2)\frac{Z_{2,2}}{R_2(2,2)} \quad (32)$$

$$(X_{1,1}+X_{2,1})=\frac{Z_{2,1}}{R_2(1,1)}-\frac{R_2(1,2)}{R_2(1,1)}\frac{Z_{2,2}}{R_2(2,2)} \quad (33)$$

The right hand term of equation (33) is known and this equation can be written in modified form as

$$\hat{Z}_{2,1}=\frac{Z_{2,1}}{R_2(1,1)}-\frac{R_2(1,2)}{R_2(1,1)}\frac{Z_{2,2}}{R_2(2,2)}$$

$$=(X_{1,1}+X_{2,1})=\sqrt{P_1}\boldsymbol{S}_{1,1}+\sqrt{P_2}\boldsymbol{S}_{2,1} \quad (34)$$

Dividing equation (34)by $\sqrt{P_2}$, we get

$$\hat{\hat{Z}}_{2,1}=\sqrt{\frac{P_1}{P_2}}S_{1,1}+S_{2,1}=0.5\,S_{1,1}+S_{2,1} \quad (35)$$

Then the transmitted symbol from first transmitting antenna considered as interference component for UE_2 can be estimated using ML decoding based QR channel decomposition aided SICscheme as

$$\widehat{\boldsymbol{S}}_{1,1}=\arg\min\left\|\hat{\hat{Z}}_{2,1}-0.5\,\widehat{\boldsymbol{S}}\right\|^2 \quad (36)$$

where,$\widehat{\boldsymbol{S}}\,\epsilon\,\underline{\boldsymbol{S}}$ and equation(31) can be written in modified form as:

$$\frac{Z_{2,2}}{R_2(2,2)}=\sqrt{P_1}S_{1,2}+\sqrt{P_2}S_{2,2} \quad (37)$$

Dividing equation (37)by $\sqrt{P_2}$, we get

$$\hat{Z}_{2,2}=\frac{Z_{2,2}}{\sqrt{P}\ R\ (2,2)}=0.5\,S_{1,2}+S_{2,2} \quad (38)$$

The transmitted symbol from second transmitting antenna considered as interference component for UE_2can be estimated using ML decoding based QR channel decomposition aided SIC scheme as

$$\hat{S}_{1,2}=\arg\min\left\|\hat{Z}_{2,2}-0.5\,\hat{S}\right\|^2 \quad (39)$$

where, $\widehat{\boldsymbol{S}}\,\epsilon\,\underline{\boldsymbol{S}}$ and substituting the value of$\widehat{S}_{1,2}$ from equation (39) in equation (38), the transmitted symbol from second transmitting antenna for user UE_2 as desired signal component can be estimated as:

$$\hat{S}_{2,2}=\hat{Z}_{2,2}-0.5\,\hat{S}_{1,2} \quad (40)$$

The transmitted symbol from first transmitting antenna for user UE_2 as desired signal component can be estimated from equation (35) as:

$$\hat{S}_{2,1}=\hat{\hat{Z}}_{2,1}-0.5\,\hat{S}_{1,1} \quad (41)$$

d) 2D Median Filtering

2D median filtering is widely used as an effective technique for removing various types of noises (salt and pepper and Gaussian) from noise contaminated image. In such filtering operation, the pixel values in the neighborhood window are generally ranked according to intensity and the middle value (the median) becomes the output value for the pixel under evaluation. In this paper, 2D Median Filtering scheme with a 3×3 neighborhood windowing mask is preferably used to make sorting of all the pixel values within the window and finding the median value and replacing the original pixel value with the median value [16].

e) Data Scrambling

Cryptography is probably the most important aspect of communications security and is becoming increasingly important as a basic building block for computer security. The binary converted data from color image of each of two users are grouped individually with each group containing 1 byte (8 bits) binary data. Each grouped binary data as plain text are encrypted with identical secret key of bit length 8 through performing XOR operation to produce encrypted/scrambled binary data[17].

IV. System Model

The simulated multiuser downlink MIMO NOMA wireless communication system is depicted in Figure 1.In such system, we assume that two users are expecting to receive two different RGB color images of identical size (height: 96 pixels and width: 96 pixels).The color images are converted into their respective three Red, Green and Blue components with each component is of 96 × 96 pixels in size. The pixel integer values are converted into 8 bits binary form and encrypted(scrambled). The scrambled binary data are channel encoded using Convolutional and LDPC scheme, interleaved and subsequently converted into digitally modulated complex signals using QPSK, DQPSK and 4-QAM [18]. The digitally modulated symbols are allocated assigned power and fed into spatial multiplexing encoder section and transmitted from each of two transmitting antennas. In receiving section of each user, signal is detected and contaminated with AWGN noise. The noise contaminated signals are processed layer wise and interference terms are cancelled out to retrieve proper signals using ML decoding based QR channel decomposition aided SIC scheme. The detected signals are fed into spatial multiplexing decoder. The decoded signals are, digitally demodulated, deinterleaved and channel decoded. The channel decoded binary data are descrambled and converted into pixel integers and filtered to recover the transmitted color images.

V. Results and Discussion

In this section, we have presented simulation results using MATLAB R2014a to illustrate the significant impact of various types of channel coding and digital modulation techniques on system performance evaluation of multiuser downlink MIMO NOMAwireless communication in terms of bit error rate (BER). It is assumed that the channel state information (CSI) of fading channel is available at the receiver with unchanged fading process throughout the whole work. The model parameters considered in our study are presented in Table 1.

Table1: Summary of the simulated model parameters

Parameters	Types
Data type	Color Image
Image Size (Both Users)	(96 x 96 x 3) Pixels
No. of user	2
Antenna configuration	2 x 2 MIMO Channel
Channel coding	½-rated Convolutional & LDPC
Digital modulation	QPSK, DQPSK and 4-QAM
Signal detection technique	ML decoding based QR channel factorization aided SIC scheme
SNR	0 to16 dB
Channel	AWGN and Rayleigh
Noise Type	Gaussian
Noise reduction image filter	2D-Median filter

The BER values of our simulated system in case of user#1(UE_1) and user#2(UE_2) under implementation of LDPC and convolutional channel coding schemes with QPSK digital modulation are presented in figure 2. It is noticeable in figure 2 that the estimated BER values for both users are approximately remain unchanged for convolutional channel coding but in case of LDPC channel coding BER values decrease slowly with increase in signal to noise ratio (SNR) values(0 dB to 16 dB). For user #1 and under consideration of typically assumed SNR value of 6 dB, the estimated BER values are 0.4981 and 0.4234 in case of convolutional and LDPC channel coding with QPSK digital modulation which implies a system performance improvement of 0.71 dB. In case of user #2 for identical SNR value, the estimated BER values are 0.4992 and 0.3882 which is indicative of system performance improvement of 1.09 dB. The estimated system performance for user #2 is better than the user #1 as comparatively more power(four times greater than user #1) was assigned to user #2.

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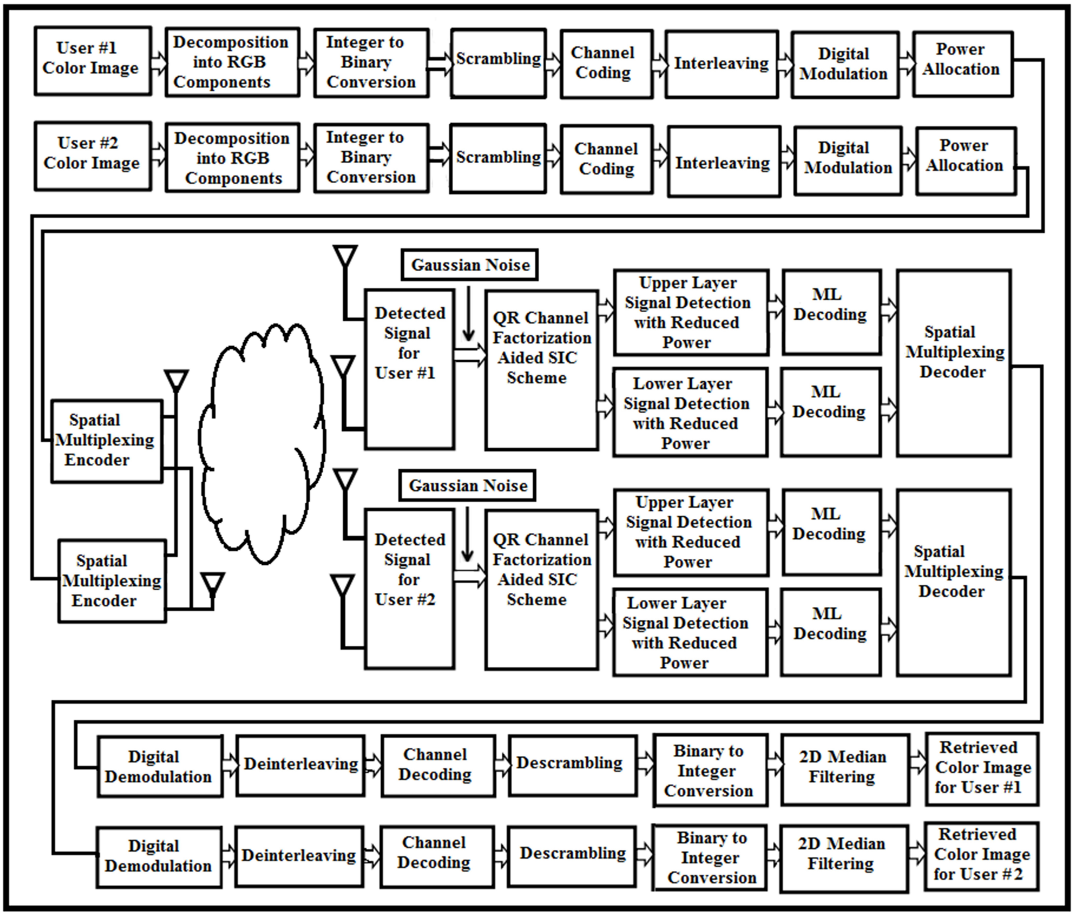

Fig.1: Block diagram of MIMO NOMA Wireless Communication System

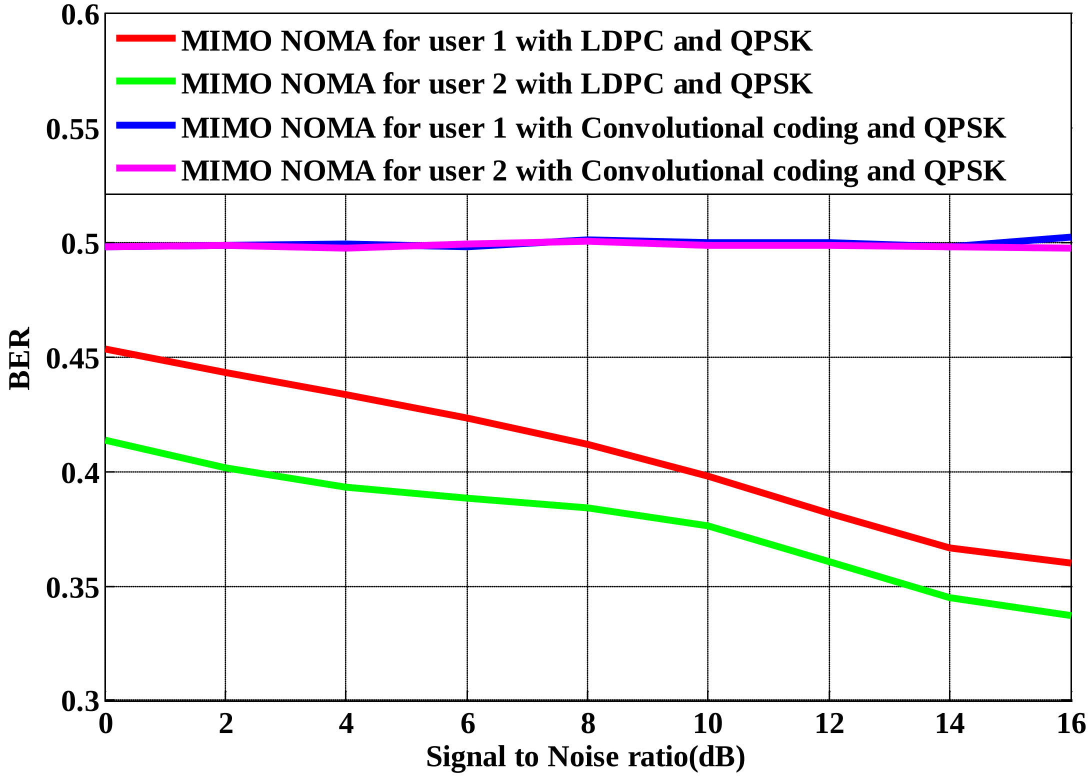

Fig. 2: BER performance of Convolutional and LDPC channel encoded MIMO NOMA wireless communication system with QPSK digital modulation scheme for image transmission

It is seen from figure 3 that the estimated BER values for both users are almost constant in convolutional channel coding. In case of LDPC channel coding, BER values decrease in higher SNR value region. Under assumption of SNR value of 10 dB in case of user#1, the estimated BER values are 0.5006 and 0.4151 in convolutional and LDPC channel coding schemes with DQPSK digital modulation which implies a system performance improvement of 0.81 dB. In case of user #2 for identical SNR value, the estimated BER values are 0.5023 and 0.4002 which is indicative of system performance improvement of 0.99 dB. For a 40%BER, a SNR improvement of around 1.8 dB is achieved in case of user #2 in comparison to user #1.

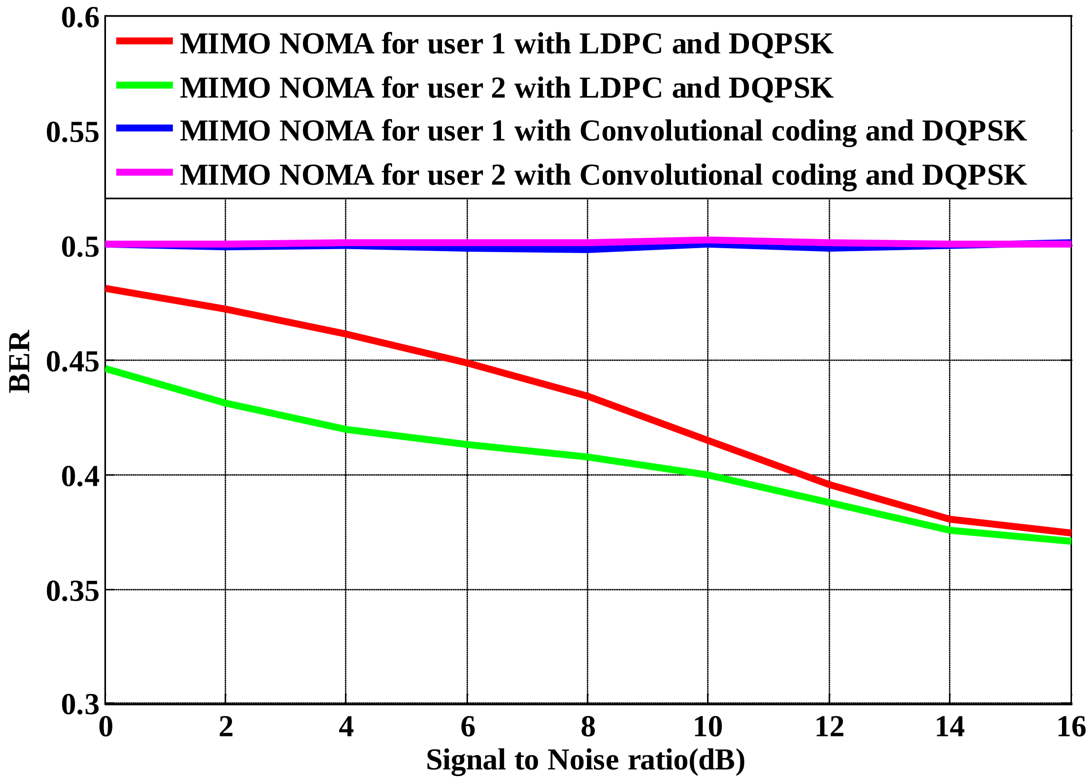

Fig. 3: BER performance of Convolutional and LDPC channel encoded MIMO NOMA wireless communication system with DQPSK digital modulation scheme for image transmission

The performance of the simulated MIMO NOMA wireless communication system in terms of estimated bit error rate (BER) in case of user #1 and user #2 under implementation of LDPC and convolutional channel coding schemes with 4-QAM digital modulation are illustrated graphically in figure 4. It is quite observable from figure 4 that the estimated BER values for both users are reasonably acceptable in both convolutional and LDPC channel coding schemes. For a typically assumed SNR value of 2 dB in case of user #1, the estimated BER values are 0.5012 and 0.3579 with the implementation of convolutional and LDPC channel coding schemes which implies a system performance improvement of 1.46 dB. In case of user #2 for identical SNR value, the estimated BER values are 0.3591 and 0.2020 which is indicative of system performance improvement of 2.50 dB. For a 20% BER, a SNR improvement of around 6 dB is achieved in case of LDPC channel coding and 4-QAM digital modulation for user #2 in comparison to user #1. At such 20% BER, a SNR improvement of around 7 dB is achieved in case of convolutional channel coding and 4-QAM digital modulation for user #2 in comparison to user #1. The transmitted and retrieved images for user #1 with white background and for user#2 with blue background under implementation of LDPC channel coding with4-QAM digital modulation at 10 dB SNR value are presented in figure 5 and figure 6 respectively. Undoubtedly, in both cases, system performance is quite satisfactory

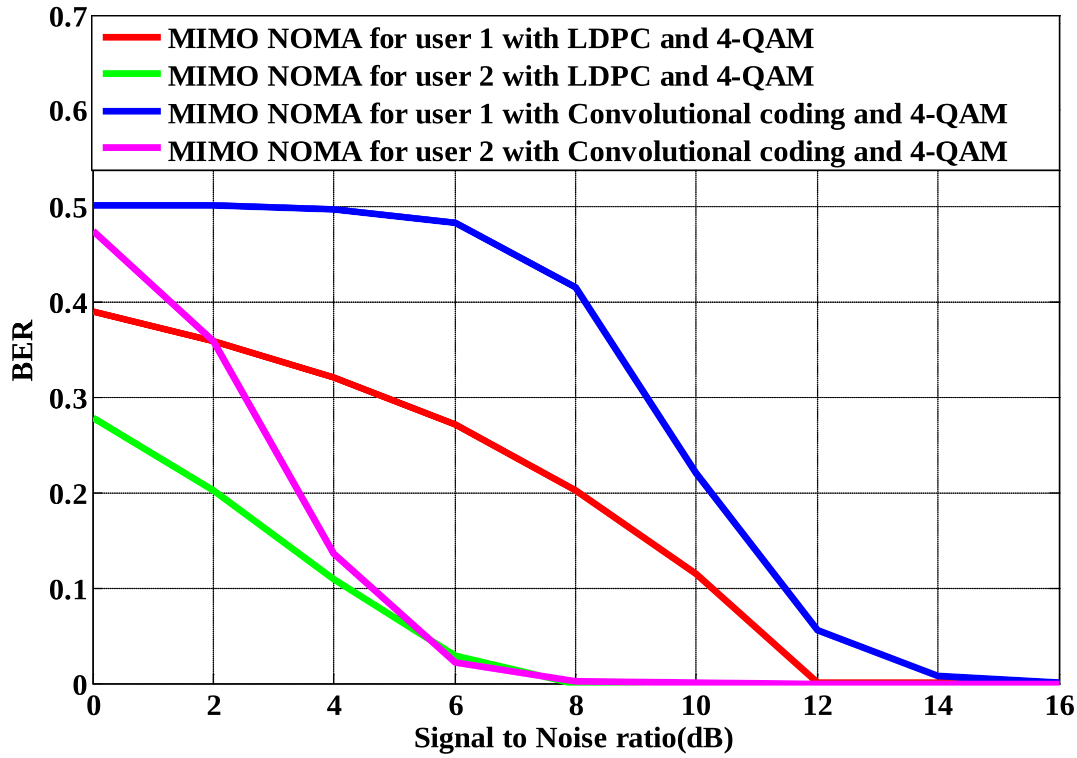

Fig. 4: BER performance of Convolutional and LDPC channel encoded MIMO NOMAWireless communication system with 4-QAM digital modulation scheme.

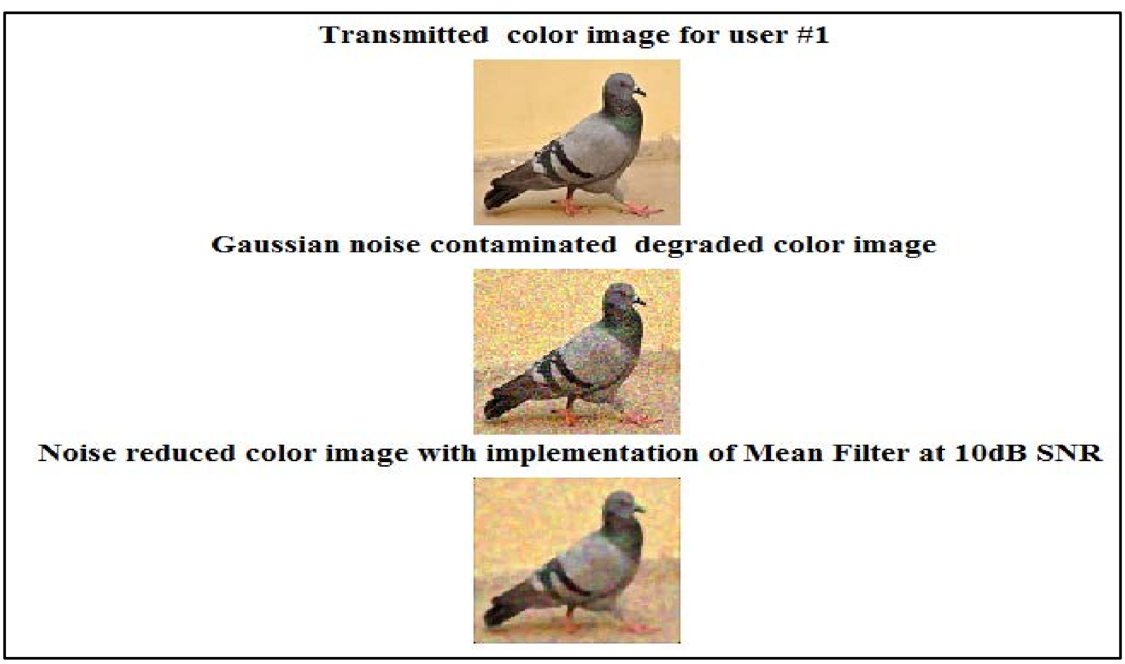

Fig. 5: Transmitted and retrieved image for user #1 of MIMO NOMA wireless communication system under implementation of LDPC channel coding with 4-QAM digital modulation at SNR value of 10 dB

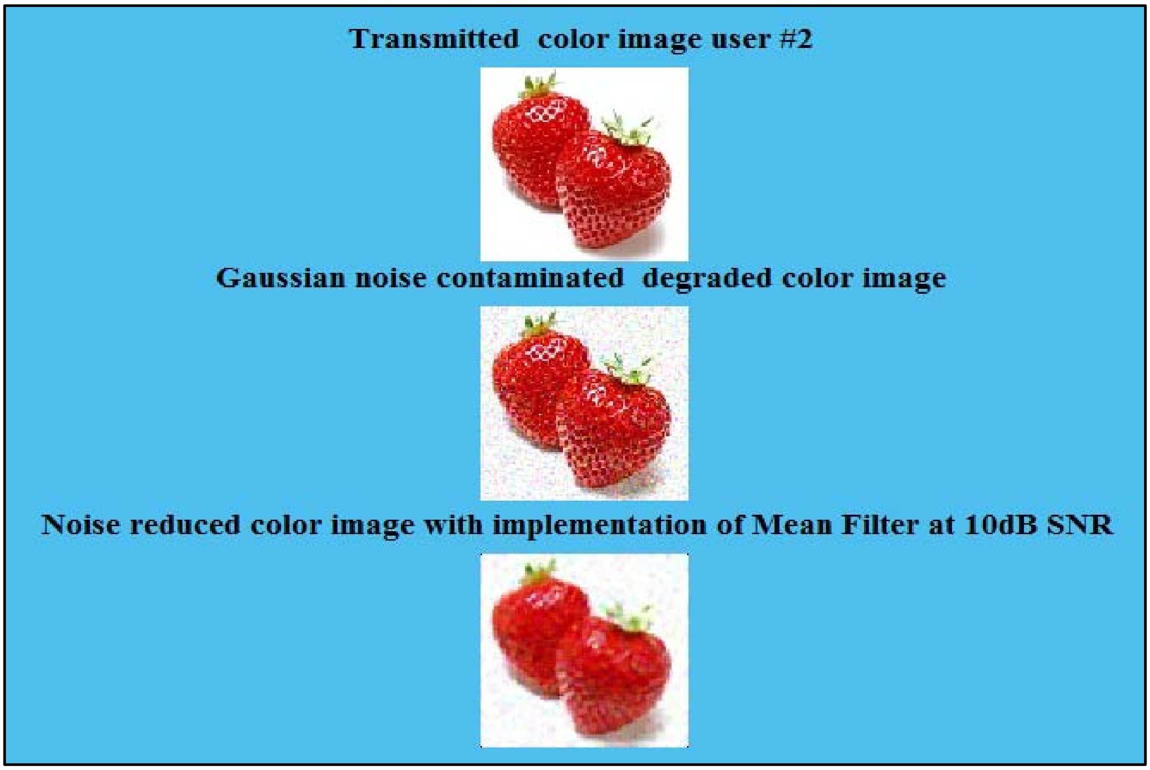

Fig. 6: Transmitted and retrieved image for user #2 of MIMO NOMA wireless communication system under implementation of LDPC channel coding with4-QAM digital modulation at SNR value of 10 dB

VI. Conclusion

In this present paper, we have made a comprehensive study on performance analysis of 5G compatible power domain user multiplexing scheme based downlink multiuser MIMO NOMA wireless communication system. Various low order digital modulation and channel coding schemes have been utilized to evaluate the system performance. On the basis of simulation results, it can beconcluded that the downlink multiuser MIMO NOMA wireless communication system is undoubtedly a robust system in perspective of signal transmission in hostile fading channel under the utilization of 4-QAM digital modulation and LDPC channel coding scheme.

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Hybrid Topology Design for Improving Network Performance

By Datukun Kalamba Aristarkus, Sellappan Palaniappan & Tatchanaamoorti Purnshatman
University of Science and Technology

Abstract- This paper is an extract of research work carried out on the computer network of Plateau State Universities Bokkos, which is located in Plateau State, Nigeria, in the western part of Africa. The existing network topology of the University was surveyed for experience of internet users and topology requirements from technical staff. Confirmed topology or layout of existing network was designed and simulated for performance outputs. This paper present the proposed topology, also referred to as the hybrid topology for improving performance. The performance output of the existing topology will be brought forward and be compared with the performance outputs of the hybrid topology for comparative purpose. In the end, the comparative result will show us if there is improvement from simulation results or not. This would help us to for-see the possibility that our new network would be better when installed.

Keywords: hybrid topology, network simulation, statistical analysis, performance parameters.

GJCST-E Classification: C.2.1, B.4.3

HYBRIDTOPOLOGYDESIGNFORIMPROVINGNETWORKPERFORMANCE

Strictly as per the compliance and regulations of:

Hybrid Topology Design for Improving Network Performance

Datukun Kalamba Aristarkus [α], Sellappan Palaniappan [σ] & Tatchanaamoorti Purnshatman [ρ]

Abstract- This paper is an extract of research work carried out on the computer network of Plateau State Universities Bokkos, which is located in Plateau State, Nigeria, in the western part of Africa. The existing network topology of the University was surveyed for experience of internet users and topology requirements from technical staff. Confirmed topology or layout of existing network was designed and simulated for performance outputs. This paper present the proposed topology, also referred to as the hybrid topology for improving performance. The performance output of the existing topology will be brought forward and be compared with the performance outputs of the hybrid topology for comparative purpose. In the end, the comparative result will show us if there is improvement from simulation results or not. This would help us to for-see the possibility that our new network would be better when installed.

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I. Introduction

Most performance of computer networks are certainly influenced by the technology, which we adopt in making network interconnections. Network topologies (Banerjee, S. et al, 1999; Cem Erosy and Shivendra PanWar, 1992; C. M. Harris, 2008; D. Bertsekas and R. Gallager, 1992) are the technology for arrangement of various computer elements like links, nodes etc. Basically network topology is the topological structure (Geon Yoon and Dae Hyun Kwan, 2006) of a computer network. In mathematics topology is concerned with the connectedness of objects which is the most basic properties of space. In simple term, network topology refers to the way in which the network of computers (Nicholas F. Maxemchuk and Ram Krishnan, 1993; Bannister, J.A. et al, 1990) is connected. Each topology is suited to specific tasks and has its own advantages and disadvantages. A most simple and good example of network topology is a Local Area Network (LAN) (F. Backes, 1988; Li Chiou Chen, 2004). A situation Where a node has two or more physical links to other devices in the network, a star topology is described. Which is the most commonly adopted topology in most campuses. In recent days there are basically two categories of network topologies: Physical topologies and Logical topologies. Physical Network Topology emphasizes the hardware associated with the system including workstations, remote terminals, servers, and the associated wiring between assets. Conversely, Logical Network Topology emphasizes the representation of data flow between nodes. This can be represented in a graph model. In this paper, we present the proposed physical topology of PSU's network.

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II. Literature Review

The existing network topology of Plateau State University Bokkos (PSU) is being investigated via interview method of survey (Datukun et al, 2016c). this has been a Local Area Network (LAN) within the Campus, also referred to as the Campus Area Network (CAN). However, CAN could interconnect LANs with geographically dispersed users to creat connectivity (Zubbair S. et al, 2012). Network Topology shows the way in which a set nodes are connected to each other by links (Qatawneh Mohammed et al, 2015), which basically is synonymous to CAN. The technology for arrangement of various computer elements like links, nodes etc describes the concept of network topologies. T1 (William, 1998), T3 (Regis, 1992), ATM (Koichi et al., 1997), ISDN (Jonathan, 2004), ADSL (Michel, 2003), frame relay (Jim, 1997), radio links (Trevor, 1999), amongst others, constitutes few of these technologies. Technologies are accompanied with various topologies and model of deployment that best suit the technology.
A network for optimal performance and meeting users' need is key in every campus, which always needs attention. Properly selecting of equipments to be deployed after considering the requirements of the users is necessary (Sood, 2007). The impact of TCP window size on application performance as against the choice of an increased bandwidth can help boost network (Panko, 2008b). the use of redundant links may also increase performance, implement load balancing and utilise links from say 92% to 55% and response time reduced by 59% (Panko, 2008; Seung-Jae, 2008). From a risk and performance point of view, it is desirable to break a larger campus networks into several smaller collapsed modules and connect them with a core layer (Robert, 1998). Distribution modules are interconnected using layer 2 or 3 core (Tony, 2002). In effect, the layer 3 switches at the server side becomes a collapsed backbone for any client to client traffic (Graham, 2010).

A Gigabit Ethernet channel can be used to scale bandwidth between backbone switches without introducing loop (Rich and James, 2008). A truncking capacity is necessarily provided into the backbone of any network design (Jerry and Alan, 2009). Hierarchical design is common in practice, when designing campus or enterprise networks (Saha and Mukherjee, 1999; Sami et al, 2002). There is no need to redesign a whole network each time a module is added or removed, provided a proper layout has being in place. But, PSU require a redesign due to topology flaws, for improving performance (Datukun et al, 2016b). the performance of the existing network was obtained, having analyzed the simulation outputs statistically as presented in Table 1 (Datukun et al, 2016d):

Table1: Values of Performance parameters

University	Parameters	Hop Count	Delay (ms)	Throughput delivered (goodput) (%)	Packets Loss (%)
PSU		103	24.0	71.8	28.1

More so, capability facilitates troubleshooting, problem isolation and network management (Damianos et al., 2002) is necessary in an ideal CAN. In a hierarchical design (Saha et al., 1993), the capacity, features, and functionality of a specific device are optimized for its position in the network and the role that it plays. The number of flows and their associated bandwidth requirements increase as they traverse points of aggregation and move up the hierarchy from access to distribution and to core layer (Awerbuch et al., 2000).

In network analysis, problems related to network mapping, characterization, sampling, inference and process can be adopted (Eric D. Kolazyk, 2009). This has to do with identifying the network components; nodes and routing system, which has to do with the analysis of the path. It could also be mathematical analysis of the network that yields explicit performance expressions (Leonard Kleinrock, 2002). This study is concerned with simulating the existing topology for proposing a better topology requirement for improving network performance.

III. Methods

The methods used for survey were interview and observation, whose questions was presented in my previous paper titled "Towards proposing network topology for Plateau State University Bokkos" with International Journal of Computer Networks and Computer Security (IJCNCS), for existing network, of which this paper is a continuation. The same questions were used to guide the collection of relevant network data by observation and further subjected to objective critism by technical staff mainly.

The paper presented the analyzed results of the survey, graph model, the physical topology, simulation outputs via simulation panel of the existing topology and further present a topology requirement for the proposed design.

In this work, we will present the topology data, the graph model, the physical design and results of statistical analysis of performance via simulation outputs for the proposed topology. The performance of the existing topology titled "Proposing minimum Performance of proposed topology in Plateau State University" published also with IJCNCS, as shown in table 1, will be brought forward to be compared for observation of performance improvement.

IV. Results

Table 2: Links and Weights of proposed Topology

Path	Descriptions	Weight (meters)
R1-S1		70
R1-S3		85
R2-S2		96
R2-S4		75
S1-S5		50
S1-S2		60
S5-S6		50
S2-S7		50
S3-S8		50
S3-S4		60
S8-S9		50
S9-S10		50
S4-S11		50
S11-S12		50
S12-S13		50

In the Table above, for every weighted link, the binary value is 1, otherwise 0. However, the Table does not include un-weighted column

Table 3: Number of nodes and links for the proposed Topology

Number of Nodes	University	Plateau State University (PSU)
Number of nodes		15
Number of links		15

The similarity in the number of nodes and links shows that the topology is not strictly "star" as it is in the existing topology were n nodes=n-1 links. From table 2 and 3, Figure 1 below is presented.

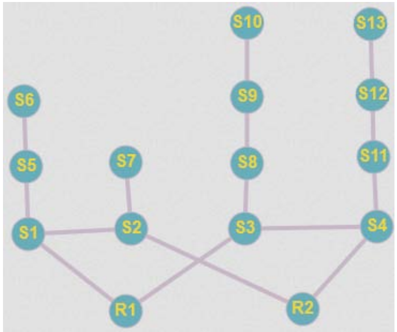

Figure 1: Graph model for PSU network

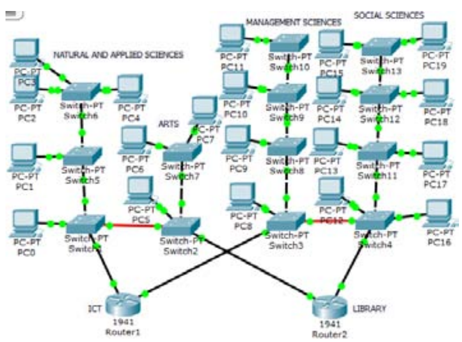

Figure 2: PSU Physical hybrid Topology

Simulation by command prompt

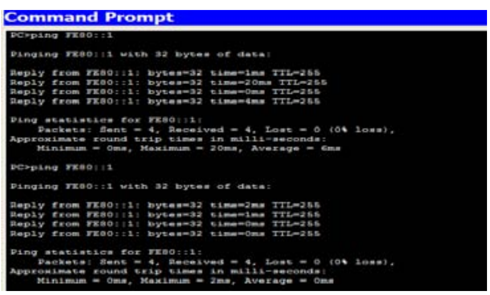

Figure3: PC 3 pings gateway

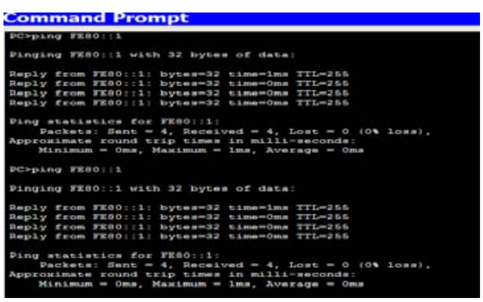

Figure 4: PC 12 Pings gateway

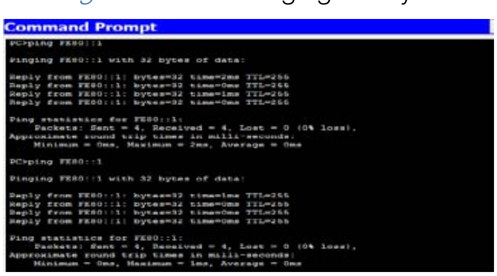

Figure 5: PC 10 pings gateway

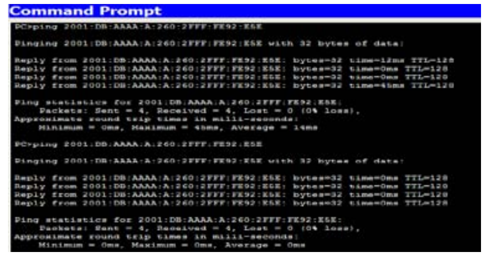

Figure 6: PC 1 pings PC 7

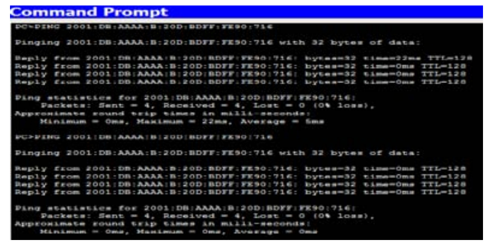

Figure 7: PC 12 pings PC 19

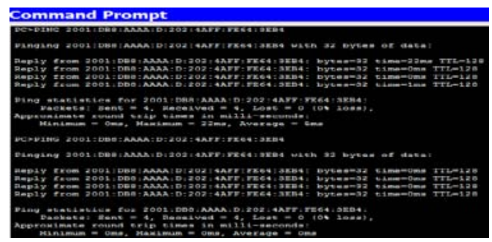

Figure 8: PC 11 pings PC 8

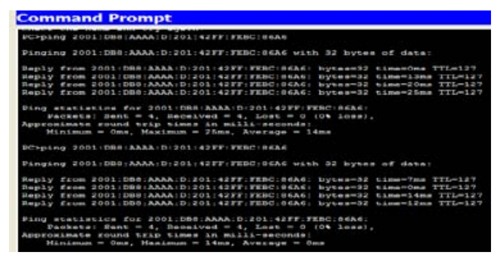

Figure 9: PC6 pings PC 9

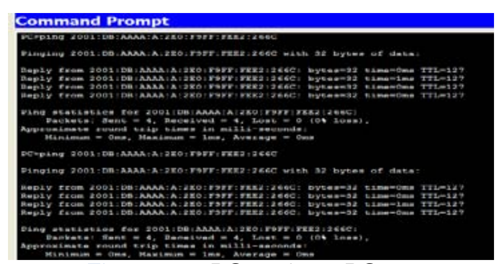

Figure 10: PC 8 pings PC 5

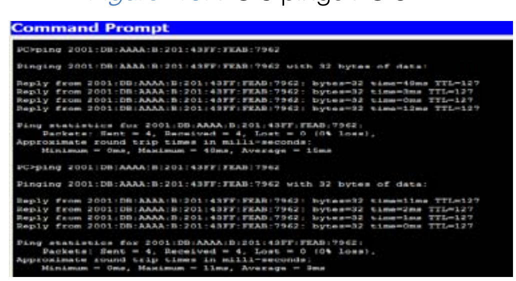

Figure 11: PC 8 pings PC 16

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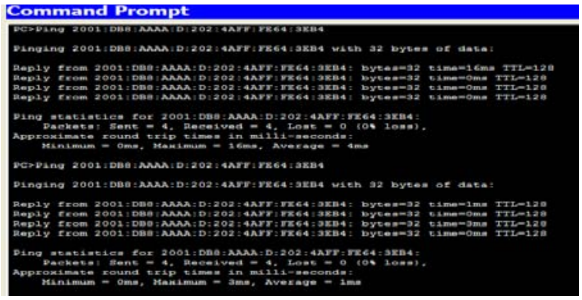

Figure 12: PC 17 pings PC 8

V. Results of Statistical Analysis

We then carry out statistical analysis as of the values obtained from Figures 3-12 as follows.

Table 4: Hybrid PSU- network Hop count

TTL	Hop Count(255-TTL) (h)	Frequency (f)	Cumulative Frequency	Hf
255	0	24	24	0
128	127	32	56	4064
127	128	24	80	3072
Total				7136

Table 4 describes the rate of hop count in the network as simulated. Average hop count $A_h = \frac{7136}{80} = 89$

Table 5: Hybrid PSU-Throughput (Packets Sent)

Packets Sent (s)	Frequency (f)	Cum. Freq.	sf
4	20	20	80
Total			80

Table 5 describes rate of packets sent as the topology is being simulated. Average packets sent $As = \frac{80}{20} = 4$. Total packets sent is 80

Table 6: Hybrid PSU-Goodput (Packets Received)

Packets Received (r)	Frequency (f)	Cum. Freq.	rf
4	20	20	80
Total			

Table 6 describes the rate of packets received (Throughput delivered). We will observe that the total packets sent in table 5 (80) is delivered in table 6 (80). Therefore the packets is 100% delivered in this simulation.

Table 7: Hybrid PSU-Packets Loss

Packets Loss (l)	Frequency (f)	Cum. Freq.	lf
0	20	20	0
Total			0

Table 6 describes the rate of packets lost as confirmed that there was no packets lost as at this simulation. Therefore, we will say that the rate of packets lost is 0% as at this simulation.

Table 8: Hybrid PSU-Transmission delay

Delay (d)(ms)	Frequency (f)	Cum. Freq	df
1	13	13	13
20	2	15	40
0	48	63	0
4	1	64	4
2	3	67	6
12	3	70	36
45	1	71	45
22	2	73	44
13	1	74	13
25	1	75	25
7	1	76	7
14	1	77	14
48	1	78	48
3	2	80	6
11	1	81	11
Total			312

Table 8 describes the rate of delay in this network simulation. Average delay

$$A_d = \frac{312}{81} = 3.85\text{ms}$$

a) Comparing Results of Hybrid Topology with Existing Topologies

Based on the specified parameters; Throuhgput, Delay and Packets Loss, we will in tabula form indicate the differences in each of the simulation results to see if there is improvement or not.

However, we also consider Hop count being a key topology determinant. It also tells how long a packet would stay on a network before it is being dropped, which contributes to the delay tendency.

Table 9: Summary of statistical analysis of Performance topology

University	Parameters	Hop Count	Delay (ms)	Throughput (%)	Packets Loss (%)
PSU		103	24.0	71.8	28.1
PSU (Hybrid)		89	3.85	100	0

VI. Discussions

We will notice that the number of nodes and links are indicated in Tables 2 and 3. For the type of topology, we will see that it is not strictly "star", since the number of nodes is equal to the number of nodes. From observation, it is clearly hybrid; semi-mesh, star and bus. Based on the given fact in tables 2 and 3, the topology was designed and simulated. The main hubs were two; located in the Library (R1) and ICT Centre(R2) connecting the four others (S1, S2, S3 and S4), the four academic faculties, being the central places of academic activities.

Here, we first consider the graph model (Figure 1), which was generated via an online graph generating platform, before subsequent physical design (Figure 2) and simulation. We further collect the values (as shown in Tables 3-8) of simulation outputs (Figures 3-12) and analyze statistically before comparing it with the previous results as shown in Table 9.

VII. Acknowledgment

I thank all the Technical staff in each University under study for being patient so far, providing me with relevant information for this research. I also thank my co-authors for all their contributions in gathering and analyzing the data of this work.

VIII. Conclusion

In conclusion, Plateau State University (PSU) would better implement the presented topology (hybrid), as this would provide the desired improvement of network performance for the Campus. This is because it has smaller hop count and delay time and no packets loss, unlike the existing network. It also has provisions for extensions, taking care of growing clients, given that the chosen main hub locations are of central academic activities and easily extensible to other areas.

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Comparative Analysis of Multicasting Routing Protocols in Mobile Adhoc Networks

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Abstract- Mobile Ad-Hoc Networks (MANETs) are autonomous and decentralized wireless systems. Mobile Ad hoc Network is a collection of mobile nodes in which the wireless links are frequently broken down due to mobility and dynamic infrastructure. Routing is a significant issue and challenge in ad hoc networks. Many Routing protocols have been proposed so far to improve the routing performance and reliability. This research paper describes comparative analysis of multicasting routing protocols in manet based on the different performance metrics like End to End delay, Throughput, Packet Loss.

Keywords: routing, protocols, DVMRP, MOSPF, PIM-SM, PIM-DM, CBT, MAODV, AMRoute, AMRIS, CAMP, ODMRP, PUMA.

GJCST-E Classification: *B.7.2, C.1.3*

COMPARATIVEANALYSISOFMULTICASTINGROUTINGPROTOCOLSINMOBILEADHOCNETWORKS

Strictly as per the compliance and regulations of:

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Gurjeet Singh α & Prof(Dr.)Vijay Dhir σ

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I. Introduction

It is the ability of a communication network to accept a single message from an application and to deliver copies of the message to multiple recipients at different locations. The goal of multicast is to provide efficient data delivery to a large set of receivers. In multicasting, senders send each data packet once and at most one copy of the packets flows through the physical links under normal conditions.

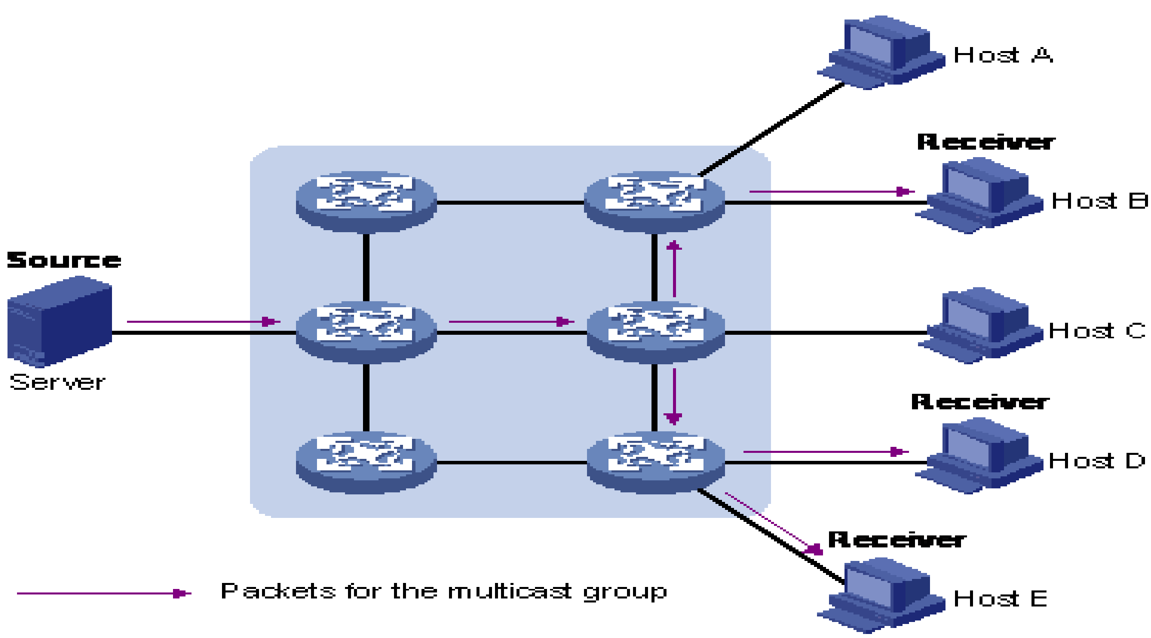

Figure 1.1: Multicasting Routing

According to diagram a Source wants to send a message to Receivers (to Host B, D and E). In case of unicast transmission, Source have to transmit the same data thrice and the bandwidth usage between the sender and the intermediate node will be thrice. In broadcasting, other Hosts (Host A and C) will get the packets although it is not relevant with the message sent, causing unnecessary bandwidth consumption. But in multicasting, only a single copy of the message is transmitted from the sender and it is copied at the intermediate node to be sent to the multicast group. A multicast group can range in size from a few nodes to several thousands.

There may be routers that do not support multicast on the network. A multicast router encapsulates multicast packets in unicast IP packets in the tunnel mode, and then sends them to the neighboring multicast routers through the routers that do not support multicast. The neighboring multicast routers remove the header of the unicast IP packets, and then

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continue to multicast the packets, thus avoiding changing the network structure greatly (Mohammad Banikazemi, 2000).

II. Literature Review

The development of a practical implementation of IP Multicasting can be traced to one Stanford University graduate student, Steven Deering, who, in the late 1980's, was working on a network-distributed operating system called "Vsystem". His challenge was to provide some protocol mechanism that would allow multicast data to flow between IP sub networks. This goal, of course, required that the data-streams be able to move through IP routers . In addition, since Steve was working with Ethernet as his LAN media, he needed to address the issue of MAC multicast addressing. The work eventually led to his doctorate paper on the subject (Deering, 1991) and, subsequently, the premier IP-Multicasting IETF document - RFC 1112.

Robert (Robert et al., 2003) discusses the factors that determine the realism of a multicast tree and to quantify multicast bandwidth gain over unicast. They developed a characterization schemes to accurately model multicast tree for a wide range of group dynamics. The work involved collecting multicast data traces from MBONE and used that data to construct a characterization model independent of network distribution. Furthermore the metrics was then used to calculate a cost model. The paper emphasize that the shape and other characteristics of the multicast tree life like depth, degree average degree frequency and the receiver distribution directly influence the efficiency of the multicast tree. Unlike some previous works which consider all the nodes of the multicast tree as receivers, they differentiate between the actual receivers and transit nodes differently in their model. The tree properties identified in this work are very useful to model real multicast tree.

Kamil (Kamil et al., 2004) developed Trace tree a mechanism to discover the multicast tree topology. The scheme uses multicast forwarding states in the router to construct a multicast forwarding tree. The scheme employs a query response mechanism in which an interested querier send a query to all multicast enable router in the network for the presence of multicast states. Each multicast node then constructs a response message and sends it back. Also each router forwards the query to downstream multicast routers. The drawback of this technique is that it needs to add extra functionality to each router in the network. Also issues arise when multicast protocol in use constructs a bidirectional tree because this could lead to duplicate response packet and a flawed multicast tree image.

Mikael (Mikael et al., 2004) studied the impact of multicast state distribution upon the IPv6 network topology. They collected a map of the IPv6 network. The multicast tree was re-partitioned using their proposed function. The author claims that by building multicast trees using this function, the number of multicast states of the top ten most loaded nodes can be reduced up to 83% at the cost of a 5% increase of the total number of multicast states in the IPv6 topology.

III. Infrastructure Based Multicasting Routing Protocols

Multicasting is the ability to transmit multiple messages to a group of receivers simultaneously using a single broadcast channel. The idea is used extensively in various internet applications, such as:

This type of data transmission can be done in several ways that differ greatly in their performance. Choosing between the possible paths is not a trivial task, depending largely on network capabilities and the desired results.

To deliver the IP multicast packets to their destinations, at least one routing protocol must be implemented in the network.

These routing protocols include:

a) Distance Vector Multicast Routing Protocol (DVMRP)
b) Multicast Extension to Open Shortest Path First (MOSPF)
c) Protocol Independent Multicast Sparse-Mode (PIM-SM)
d) Protocol Independent Multicast Dense-Mode (PIM-DM)
e) Core-Based Tree (CBT)

IV. Infrastructure-Less Multicast Routing Protocols

A mobile ad hoc network lacks a fixed infrastructure and has a dynamically changing topology. The nodes move freely and independently of one another. Ad hoc networks are heavily used in emergency situations where no infrastructure is available, for eg. battlefields, disaster mitigation etc.

(Corson et al., 1999) Design of multicast routing protocol is difficult due to the inherent uncertainty and unpredictable dynamism. Several multicast protocols have been proposed for mobile ad hoc networks. Based on the network structure along which multicast packets are delivered to multiple receivers, multicast protocols can be broadly categorized into two types, namely tree-based multicast and mesh based multicast. The tree structure is known for its efficiency in utilizing the network resource optimally, while tree based protocols are generally more efficient in terms of data transmission. Mesh based protocols are more robust against topology changes due to availability of many redundant paths between mobile nodes and result in high packet delivery ratio. On the other hand, multicast

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mesh does not perform well in terms of energy efficiency because mesh-based protocols depend on broadcast flooding within the mesh and therefore, involving many more forwarding nodes than multicast trees.

In summary, the broadcast forwarding in mesh based protocols produces redundant links, which improves the packet delivery ratio but spends more energy than the tree-based multicast. The tree approach has some other drawbacks. The paths are non-optimal and traffic is concentrated on the tree, rather than being evenly distributed across the network. They are not robust to mobility as there is no back up path between a source and a destination, besides that, all tree based protocols need a group leader (or a core or a rendezvous point) to maintain group information and to create multicast trees.

A multicast packet is delivered to all the receivers belong to a group along a network structure such as tree or mesh, which is constructed once a multicast group is formed. However, due to node mobility the network structure is fragile and thus, the multicast packet may not be delivered to some members. To compensate this problem and to improve the packet delivery ratio, multicast protocols for ad hoc networks usually employ control packets to periodically refresh the network structure.

Following are the protocols to cope with multicast in ad-hoc networks.

1. Multicast Ad hoc On-demand Distance vector protocol (MAODV)
2. d-hoc Multicast Routing (AMRoute)
3. Ad hoc Multicast Routing protocol (AMRIS)
4. Core Assisted Mesh Protocol (CAMP)
5. On Demand multicast routing protocol (ODMRP)
6. Protocol for Unified multicasting through Announcements (PUMA)

V. Simulation Enviornment

In this PAPER we have one source node which is generating UDP connection. Simulation experiments were performed to determine whether some multicast routing protocols are more appropriate in certain traffic conditions and subscription level circumstances. The experiments were performed in ns-2, a discrete event simulation environment that is freely available.

Simulation of Fixed Network Protocols: Nodes and Links are demanded in wired network simulation for creating the topologies. Agent and traffic frame are attached to the nodes. And all the nodes are connected by link, the agent too.

Nodes: There are two important roles of a node in NS2. As a router, it forwards packets to the connecting link based on a routing table.

Links: There are three link types in NS2 which are Simplex-Link, Duplex-Link and Duplex-Intserv-Link.

Agents: An agent is a program that gathers information or performs some other service without our immediate presence and on some regular schedule. UDP a basic UDP agent is used in simulations.

Traffic Generators: Application can be classified into traffic generators (Traffic/CBR, Traffic/Exponential, Traffic/Pareto).

Traffic distribution to use for multicast

Constant bit rate (CBR): In this process, the packets are generated at the stations at a constant rate. This is one of the most simplistic models possible and exactly models CBR services.

A CBR traffic generator creates a fixed size payload burst for every fixed interval.

Table 1.1: CBR Traffic

Variable	Default value	Default value
Packet Size	210	Application payload size in bytes
Random	0 (false)	If true, introduce a random time to the inter-burst transmission interval.

Table 1.2: Simulation Parameters for Fixed Area Protocols

The simulation parameters	Parameter Value
Link bandwidth	100Mb/s
Link delay	10 ms
Session bandwidth	200kb/s
Join interval	1 (first receiver at0.03sec)
Number of receivers	4,8,16,32
Simulation time	8 s

Table 1.3: Simulation parameters for Mobile Adhoc Network Protocols

Parameter	Value
Area	1500*300
Number of Nodes	4,8,16,32
Simulation Time	8 sec
Transmission Range	250meters
Sending rate	2 packets per second
Node speed	0 -20m/s
Packet size	256 bytes
Bandwidth	100Mbps

Similarly, the simulations were performed by varying the size of group from 4 to 32 PUMA and MAODV are both receiver-oriented protocols. However, PUMA is a mesh-based protocol and provides multiple routes from senders to receivers. MAODV, on the other hand, is a tree based protocol and provides only a single route between senders and receivers.

VI. Results

In this paper, we present the simulation results with different multicast routing protocols that we have described in the previous section. The simulation is done with discrete event simulation namely ns 2 version 2.35. Models in ns are created by defining nodes and connecting them with links to form some network topology.

As well as Infrastructure based protocols we also have evaluated the performance of PUMA and compared it with MAODV in terms of routing overhead, throughput, packet delivery fraction and end-to-end delay in NS-2.35. The obtained results are illustrated below. Multicast routing protocols are compared on the basis of different Performance Metrics. These performance Metrics are:

a) End to End Delay

Time elapsed between the generation of a packet at a source and the reception of that packet by a group member. Delay is the amount of time that it takes for a packet to be transmitted from one point in network to another point in a network. It refers to the time taken for a packet to be transmitted across a network from source to destination.

End-To-End delay was monitor at each multicast listener. The delay for CBT was relatively more than the rest of the protocols. CBT protocol also created a shared tree but the delay was much higher. The reason is the processing time at the RP. The delay has a fairly constant value for all the four protocols. second highest delay is produced by PIM-SM. All the three Remaining Protocols shows almost constant delay after one second which is not the case in CBT. They delay is highest in last time interval as the distance is also highest to move from source to destination(farthest receiver).

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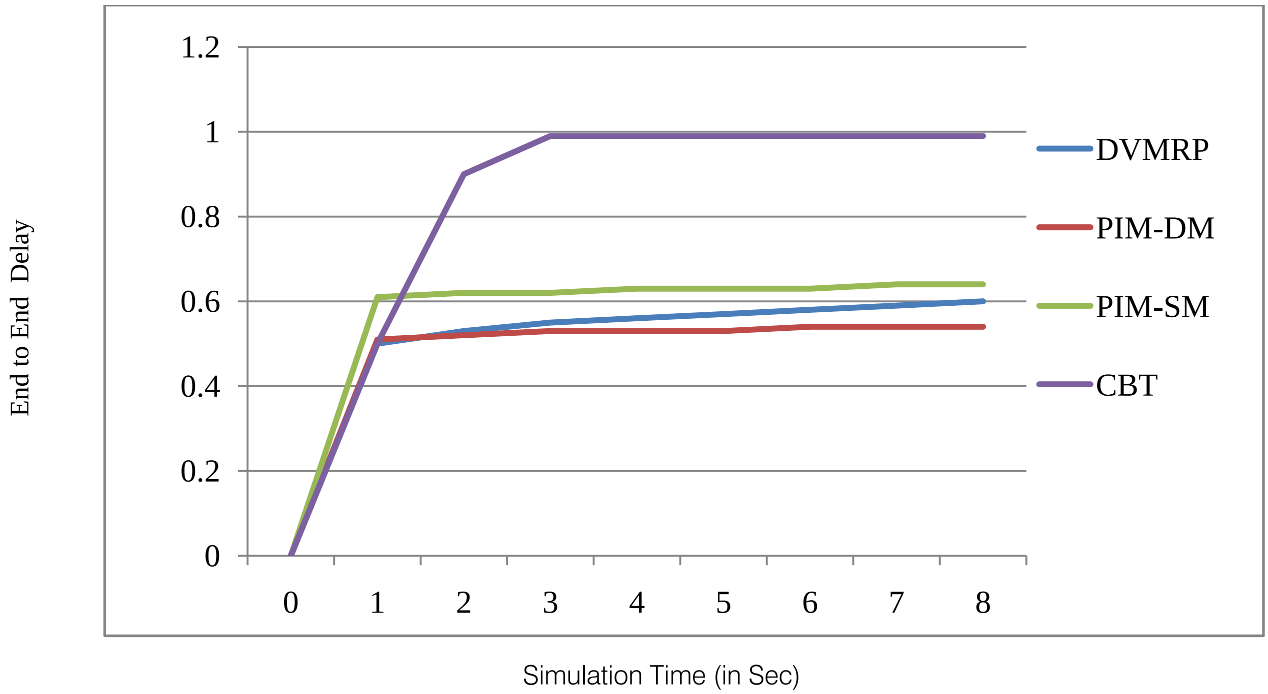


Figure 1.2: End To End Delay (Infra. Based)

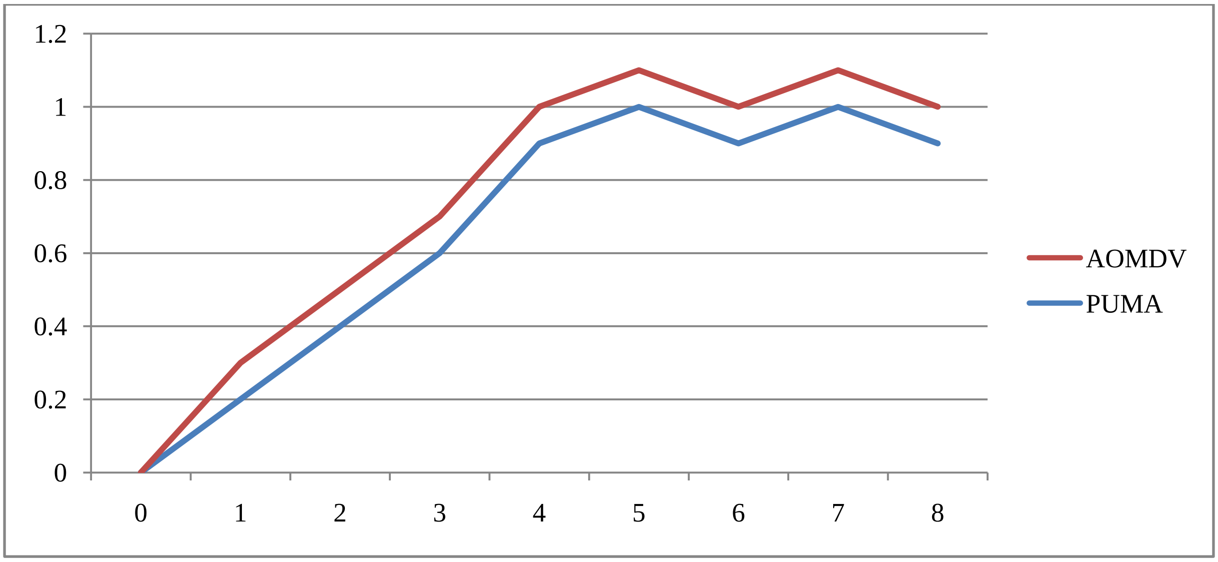
End to End delay for different Protocols according to varying topology is shown in table above. For real time application or critical applications end to end delay should be less. Lesser the end to end delay, better will be the performance.

End to End delay for all Multicast routing protocols is shown in the graph corresponding to the simulation time. End to End delay bears large variation in the graph, somewhere it is more and somewhere it is less. PIM-DM is better than DVMRP when comapred according to end to end delay metric. And among DVMRP,PIM-SM,PIM-DM and CBT , PIM-DM provides less end to end delay.

Table 1.4: End To End Delay (Infra. Based)

No.of Group Members	Four	Eight	Sixteen	Thirty Two
DVMRP	$10426964 \times (10)^{-9}$	$10426984 \times (10)^{-9}$	$10426949 \times (10)^{-9}$	$10426958 \times (10)^{-9}$
PIM-SM	$10426571 \times (10)^{-9}$	$10426727 \times (10)^{-9}$	$10426853 \times (10)^{-9}$	$10426789 \times (10)^{-9}$
PIM-DM	$10426856 \times (10)^{-9}$	$10426967 \times (10)^{-9}$	$10426769 \times (10)^{-9}$	$10426770 \times (10)^{-9}$
CBT	$11227 \times (10)^{-6}$	$11227 \times (10)^{-6}$	$11227 \times (10)^{-6}$	$11227 \times (10)^{-6}$

In ad-hoc networks End to End to End delay is as following.



Simulation Time (in Sec)

Figure 1.3: End To End Delay (Infra. Less)

Among AOMDV and PUMA ,AOMDV has higher End to End delay.PUMA has less End to End Delay. PUMA and MAODV are both receiver-oriented protocols. However, PUMA is a mesh-based protocol and provides multiple routes from senders to receivers. MAODV, on the other hand, is a tree based protocol and provides only a single route between senders and receivers.

Table 1.5: End To End Delay (Infra. Less)

No. of Group Members	Four	Eight	Sixteen	Thirty Two
MAODV	9735580 x $(10)^{-9}$	9795479 x $(10)^{-9}$	1x$(10)^{-6}$	2134430 x$(10)^{-6}$
PUMA	1 x $(10)^{-16}$	1 x $(10)^{-16}$	1 x $(10)^{-16}$	1 x $(10)^{-16}$

Based on the results shown above higher End-to-end delay values imply that routing protocol is not fully efficient and causes congestion in the network. As against the MAODV,
PUMA exhibits lesser values of End-to-end delay.

End-2-End delay = time (in seconds) when packet was received by OTHER NODE - time (in seconds) when packet was sent by CURRENT NODE (for calculations)

b) Throughput

Throughput is a generic term used to describe the capacity of the system to transfer data. Throughput is nothing but the bandwidth of the transmission channel. Throughput is the rate at which network sends or receives data. Throughput is much harder to define and measure because there are numerous ways through which throughput can be calculated:

- The packet or byte rate across the network.
- The packet or byte rate of a specific application flow.
- The packet or byte rate of host to host aggregated flows, or
- The packet or byte rate of network to network aggregated flows.

We have calculated throughput using following formula:

Throughput = Packets received / Packets forwarded

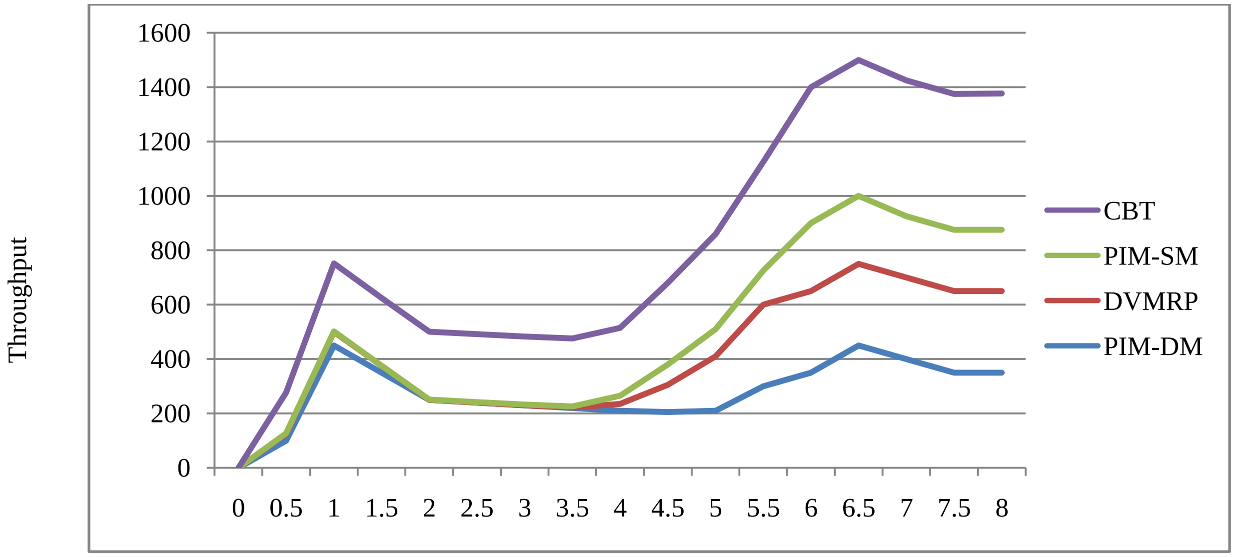


Figure 1.4: Throughput (Infra. Based)

Table 1.6: Forwarded Packets (Infra. Based)

No. of Group Members	Four	Eight	Sixteen	Thirty Two
DVMRP	2626	12249	33003	61333
PIM-SM	2608	12129	58822	32587
PIM-DM	2873	12231	35297	65251
CBT	4425	13902	39744	60739

Throughput of CBT is higher than all protocols while PIM-DM does not achieved the expected throughput ,same is the case for DVMRP but it performs good as compared to PIM-DM. Both

Sparse mode protocols performs very well as compared to both compared to dense mode protocols .The basic reason behind this is initial flooding by DVMRP and PIM-DM. Thats why the packets meant for actual receivers are too less as compared to sent packets

In ad-hoc networks PUMA outperforms as compared to MAODV because it relies on very good technique of announcements. The chances of failure are less, because it can choose its leader dynamically without the interference of Network designer.So there is no single point failure like problems.

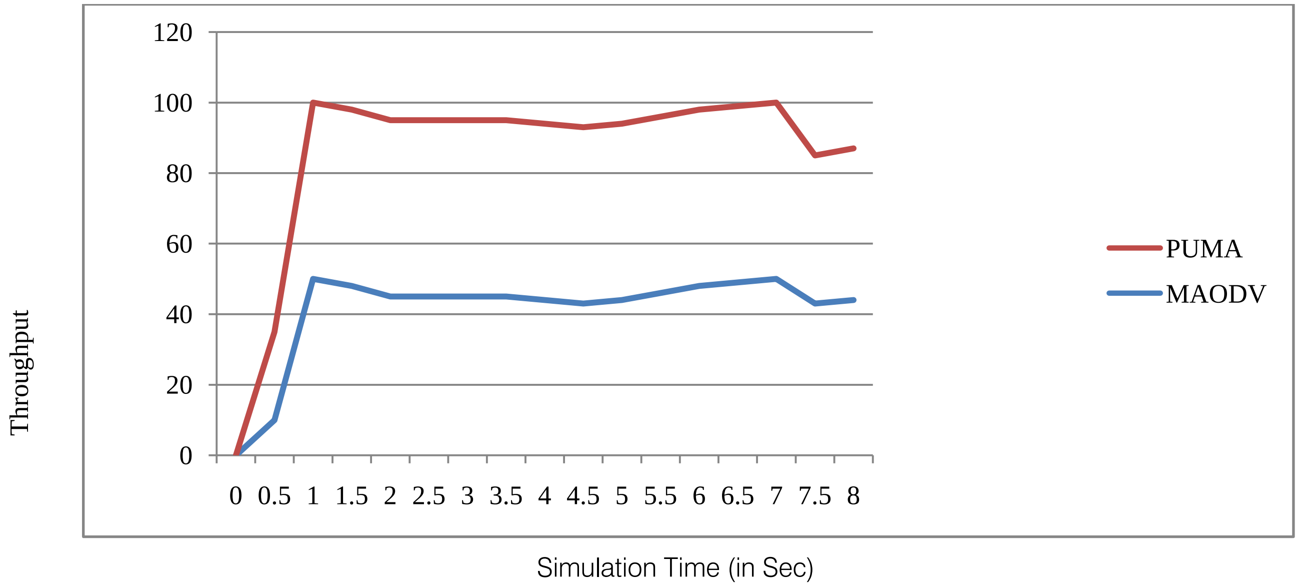


Figure 1.5: Throughput (Infra. Less)

Figure 1.5 shows the Throughput analysis. For increasing number of nodes the throughput of PUMA is higher than the MAODV.

Table 1.7: Throughput (Infra. Less)

No. of Group Members	Four	Eight	Sixteen	Thirty Two
MAODV	32	39	46	50
PUMA	93	97	100	100

Based on the simulation results shown above, the packet delivery fraction of PUMA is higher than MAODV for varying number of nodes.

c) *Packet Loss*

Packet loss is where network traffic fails to reach its destination in a timely manner.

Packet Lost = amount of packets received - amount of packets forwarded

There are three causes of packet loss in the network

- A break in Physical link that prevents the transmission of a packet
- A packet that is corrupted by a noise and is detected by a checksum failure at downstream node and Network congestion that leads to buffer overflow.

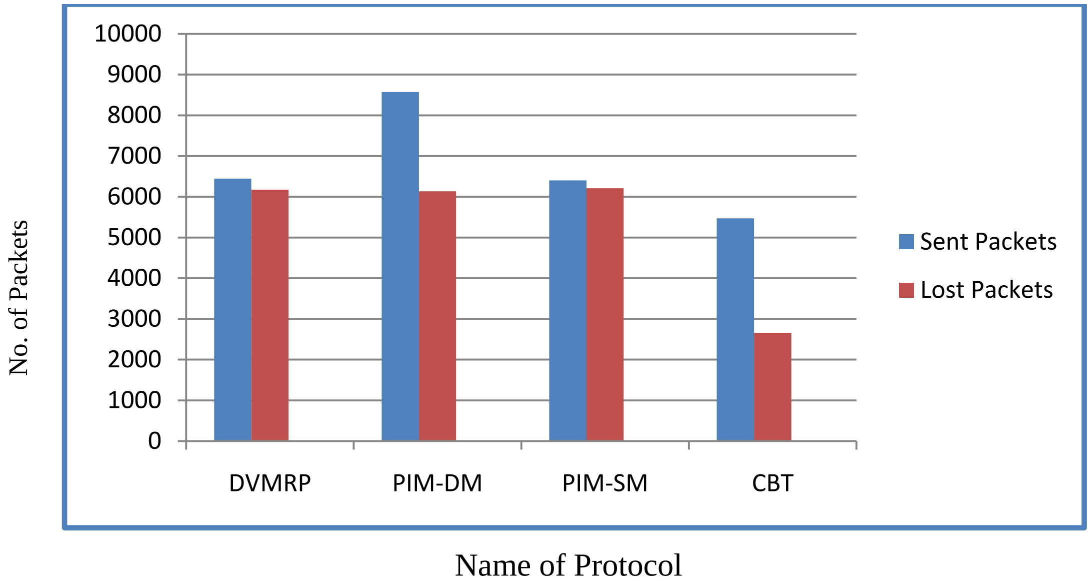


Figure 1.6: Packet Loss (Infra. Based)

The no. of packets that are lost during simulations and can be computed by subtracting the no. of received packets from forwarded packets. The no. of Packets lost by CBT are much less as compared to all another protocols.

Table 1.8: Packet Loss (Infra. Based)

No. of Group Members	Four	Eight	Sixteen	Thirty Two
DVMRP	5317(5373)	6086(6211)	6172(6447)	6180(7626)
PIM-SM	5437(5444)	6184(6195)	6211(6230)	6211(6252)
PIM-DM	5323(5608)	6058(6155)	6136(8572)	6147(11463)
CBT	3411(5435)	4157(6181)	2657(5470)	4186(6210)

In case of ad-hoc only 10 percent as compared to infrastructure based are forwarded.

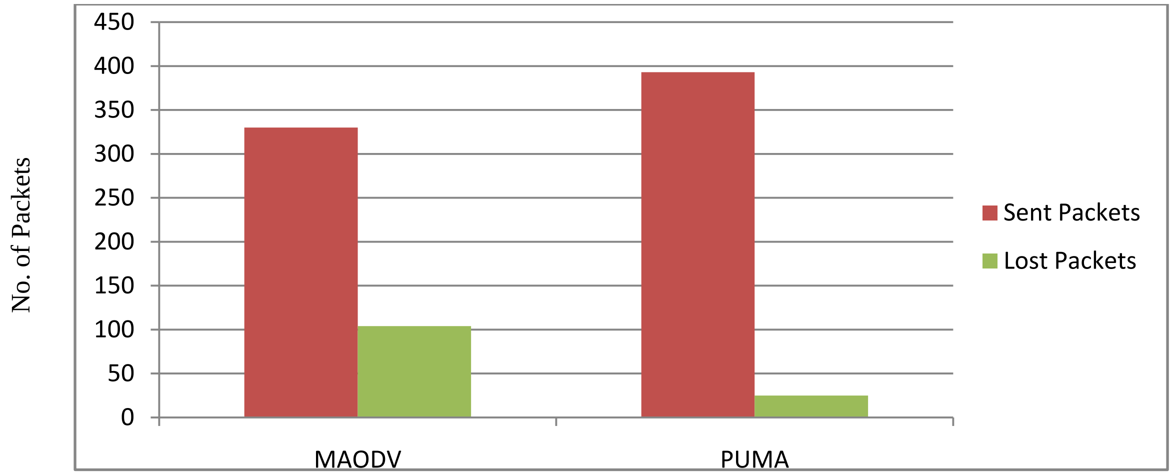


Figure 1.7: Packet Loss (Infra. Less)

The no of packets los by PUMA is one fourth of the packets los by MAODV protocol.

Table 1.9: Packet Loss (Infra. Less)

No. of Group Members	Four	Eight	Sixteen	Thirty Two
MAODV	30(200)	80(320)	100(325)	111(330)
PUMA	10(200)	17(250)	20(380)	25(400)

VII. Conclusion

All multicast routing protocols are different from each other on the basis of performance was measured in terms of performance metrics, there was no convincing Protocol(in all scenarios) in Infrastructure based environment. Therefore, if a network designer is only interested in function of the multicast routing protocols, then he is free to choose any one of the multicast routing protocols, but good performance can not be achieved in all respects.

When Multicast routing protocols are compared on the basis of End to End delay then all protocol shows very different results then PIM-DM give better performance that is less delay, while CBT has maximum delay so it best to choose PIM-DM. Multicast routing protocols performance differed when compared in terms of performance metrics. The experimental results suggest that configuration parameters do indeed play a role in how well the various multicast routing protocols perform. A network designer should be aware of this fact and should choose an appropriate Routing Protocol. In general, in various situations DVMRP and PIM-DM performed similarly to one another in a specific traffic pattern context.

PUMA incurs far less overhead as compared to MAODV. It has higher packet delivery fraction and throughput. The lesser values of End-to-end delay imply a better performance than other protocol. So, PUMA has been selected best from infrastructure less protocols.

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Design of Heterogeneous Wireless Mesh Network for LTE

By Jerin M James & Dr. Milind Thomas Themalil

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Keywords: mesh network; LTE; heterogeneous network.

GJCST-E Classification: C.2.1, C.1.3

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Design of Heterogeneous Wireless Mesh Network for LTE

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Abstract- Congestion in LTE and other cellular networks can be reduced by cell splitting and by buying more spectrum. But due to the heavy licensing fee and the cost of setting up new base stations, service providers have started to resort to the unlicensed spectrum, particularly the ISM band to offload some of the data from the LTE network locally, in areas of heavy user base. There does not exist a long-term and standard solution although some efforts have been made to enable cooperation between the different networks like LTE and IEEE 802.11. Thus, a new architecture and accompanying routing protocol is proposed to enable a tighter integration between different networks to improve QoS and overall performance of the combined heterogeneous network. The performance improvement is 2-3 times more than LTE and Wi-Fi networks when used independently, even when twice the bandwidth is used by the component networks alone.

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I. Introduction

Present cellular networks, including LTE, suffer from the increase in the number of user devices connected to the network in a region. The network-wide performance of LTE can be improved by setting up more Base Stations for planned frequency reuse and by gaining more spectrum to accommodate a greater number of users. The cost of expanding the infrastructure by setting up more Base Stations in crowded regions and the high spectrum licensing costs make this approach unattractive to service providers. Further, methods such as cell-splitting require extensive field-study to determine the appropriate location for new BSs. Base Stations in large open areas with relatively low number of users should cover more of the region, compared to BSs in areas of high demand. In practice, there is no alternative long-term solution for situations such as temporary changes in demand due to crowded events and network coverage problems at cell edges, although a recent trend to offload some of the LTE data to Wi- Fi has shown positive results.

IEEE 802.11 or Wi-Fi network access technology is a popular and mature alternative for accessing the Internet without the spectrum licensing costs as it operates in the ISM band or Industrial, Scientific and Medical bands released for local networking. But, the limited range of Wi-Fi APs or Access Points restricts the usage of the technology to local and personal area networking and networking up to a few kilometers using directional antennas. The support for mobility is limited to those devices that can be classified as nomadic rather than true mobile devices, unlike cellular technologies.

Wireless Mesh Networks using IEEE 802.11 offer a mesh topology to access Internet services and thus support expansion of the network similar to ad-hoc networks without centralized infrastructure. Mesh networking technologies also provide greater fault tolerance and network reliability as multiple paths can exist from a source to a destination. However, the wireless link quality in such networks is not guaranteed due to interference among densely located Wi-Fi mesh nodes. This and the multihop nature of mesh networks will mean a lower network capacity. Packet-loss and resource consumption in multihop networks is comparatively very high due to the very nature of the network. Further, since mobile wireless nodes can create links dynamically in the mesh network, nodes can get isolated and form island nodes which cannot communicate with the rest of the network. The conversion of a node in a multihop path into an island node may not be immediately registered by the other nodes in the path since ad-hoc routing and management protocols are not optimized for mesh networks.

Next generation networks must integrate the basic features offered by these networks, while addressing the limitations of the individual networks, for improved service quality and data rate without buying more spectrum or investing in large centralized infrastructure. Such a solution is preferred due to the wide adoption of LTE cellular technology and since it supports the coexistence of the different wireless technologies and wired networks. The combined network uses the existing centralized infrastructure and can be updated following changes in demand with incremental additions to the network as and when needed. The expansion of the network does not require setting up more centralized infrastructure. Such a network which combines Wi-Fi mesh network and LTE can utilize the diversity or heterogeneity of the different

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technologies to overcome the limitations of each of the access technology when employed independently. The mesh part of the network can be expanded in proportion to increase in demand thus improving scalability of the combined network, and the multihop nodes of Wi-Fi mesh can relay packets from/to conventional mobile nodes which are at the edge of the LTE cell, thereby essentially improving coverage of the LTE network. Further, fault-tolerance of the heterogeneous network is improved considerably since redundancy is introduced by the mesh topology and by the use of multiple network access technologies which can eliminate the creation of island nodes. A heterogeneous network utilizing LTE and switch) between the transmission technologies is developed in the form of a heterogeneous routing protocol. The routing protocol is composed of two parts: a system to populate and maintain the routing tables of the heterogeneous devices which the architecture employs, and a heterogeneous routing algorithm for utilizing the routing tables. The performance of the proposed architecture which incorporates the routing

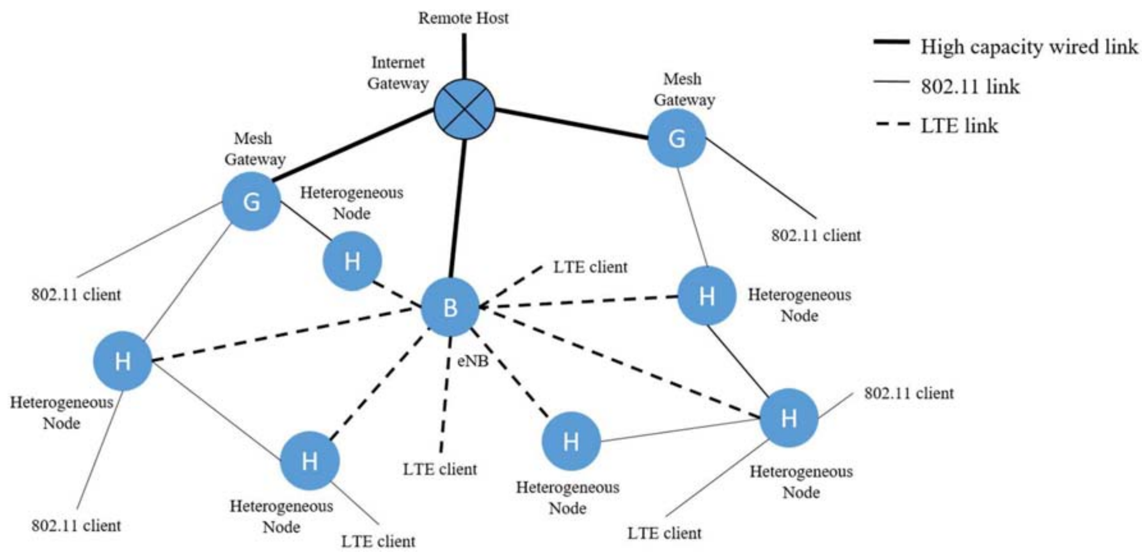

Fig. 1: Heterogeneous wireless network

Wi-Fi mesh can distribute load across the network technologies by offloading some of the LTE packets to the Wi-Fi network to improve performance and handle congestion in LTE network.

The level of integration should be such that the combined network act as one single network for obtaining maximum performance. Interoperability of the different technologies must be considered since many devices use different network access technologies, underlying protocols and operating systems. The heterogeneous network architecture should be capable of avoiding long multihop paths in the mesh network and island nodes to reduce packet loss and resource consumption for a better QoS. Other challenges to achieving this include unavailability of a mechanism for heterogeneous routing i.e., switching between the two transmission technologies, considering the heterogeneity in protocols used by the two technologies. Further, heterogeneous routing requires that the routing or switching protocol operate with close association to the MAC layer since packets from LTE have to be offloaded to Wi-Fi network and vice-versa based on network parameters of each access technology. Thus, the heterogeneous routing protocol should invariably be a cross layer routing protocol.

A new heterogeneous wireless mesh network architecture which introduces tight integration between the two network access technologies IEEE 802.11s wireless mesh and LTE is proposed. Further, an accompanying mechanism to route (or protocol is evaluated using the open-source discrete-event network simulator NS3 (Network Simulator 3) for its community support, flexibility and support for LTE networks, IEEE 802.11s mesh and creation of heterogeneous nodes.

II. Existing System

The definition of 'WiFi offloading' has been shaped by the growth of LTE technology to mean WiFi offload or handover between LTE network and WiFi network. For mobile phone users, it can mean access to wider bandwidth probably at a lower cost or for free. For mobile network operators, it would help reduce the load on the LTE network by offloading the subscriber to WiFi network. The service providers may not be able to charge for WiFi network usage as for LTE network but they may be able to get some gain from load balancing and still keep some portions of the money from the mobile user by directing to switch to the WiFi network serviced by the mobile network operator. Thus, with respect to end-user experience, several models for WiFi offloading currently exist. In UEinitiated Wi-Fi offloading, the user equipment is initially connected to the LTE network while there is no WiFi network available. The user switches to the WiFi network when the UE is within range of the WiFi network based on certain criteria. Thus the handover between the networks is initiated from the user side. Similar to UE-initiated offloading, in network initiated WiFi offloading, the user equipment is initially connected to the LTE network while there is no WiFi network available. The user switches to the WiFi network when the UE is within range of the WiFi network based on certain criteria. Here, the handover between the networks is initiated by the network. The Wi-Fi network is coupled to the LTE network in two ways. one is through a Trusted Access Point and the other one is through Non-Trusted Access Point. In Trusted Access, the WiFi Security is protected by the 3GPP network, Thus, the end user does not need any separate authentication process between 3GPP and non-3GPP Network. For Non- Trusted Access, WiFi Security is not protected by the 3GPP network, the user has to go through separate authentication process between 3GPP and non-3GPP Network, the non- 3GPP network here being the WiFi network.

The main difference between the existing system for WiFi Off loading and offloading in the heterogeneous network is that setting up the heterogeneous network architecture requires changes to be made only in the region covered by a single eNodeB and not to the remaining parts of the network.

III. Network Architecture

The heterogeneous network architecture is built with the LTE Base Station (eNodeB) at its center to extend and improve the features of the LTE network in the region covered by the Base Station. That is, the architecture covers a single cell of the LTE network and each cell uses the same architecture to improve capacity. Close proximity of the LTE and Wi-Fi transmitters cannot cause interference as the two network technologies use different frequency bands. Mesh Gateway nodes in the Wireless Mesh Network (WMN) connect it to the Internet Gateway. The Internet Gateway is connected by high-capacity wired path to the Evolved Packet Core (EPC) of the LTE network and also connects the eNodeB. Thus, the Internet Gateway acts as the server to provide Internet access to the heterogeneous network. Many nodes which support multiple transmission technologies called Heterogeneous Nodes (HetNodes) are positioned across the area of the LTE cell and form the backbone of the WMN. This means that the HetNodes support multiple network interfaces and thus each HetNode can communicate with its neighboring HetNode using either LTE transmission technology or Wi-Fi links. Conventional clients such as mobile phones or laptops can connect to the Mesh Gateways or the HetNodes and/or the LTE Base Station, or by using wired interfaces of the Mesh Gateways or HetNodes.

In the downlink (DL) scenario, i.e., while a packet meant to reach a client node connected to the heterogeneous network from the Internet travels to the network, the Internet Gateway is responsible to route the packet to either LTE or Wi-Fi network through one of its interfaces. Thus, the architecture does not support switching back to LTE after the Internet Gateway routes the packets to the Wi-Fi network. In the uplink (UL) case, multiple interfaces of the HetNodes can be utilized.

Each of the interfaces in a heterogeneous node will have a different network address or IP address. There should be a mechanism to list the addresses of each node in the network with the Internet Gateway. The Internet Gateway should also be aware of the associations between nodes in different levels of the multi-level architecture primarily because it is responsible for switching between transmission technologies in the downlink. Thus, each type of node maintains routing table(s) which are forwarded to the Internet Gateway using control messages, and the routing tables are also utilized by the heterogeneous routing algorithm to route packets between the different transmission technologies. The routing protocol also specifies the access technology to be used for communicating control messages to update the routing table of the Internet Gateway.

Each HetNode should maintain routing table for routes to every other heterogeneous node in the Wi-Fi mesh network. This is achieved using OLSR (Optimized Link State Routing) ad-hoc routing protocol. HetNodes should also maintain a list of available Mesh Gateways and a default Mesh Gateway. The OLSR protocol is extended using hop count to a Mesh Gateway and number of nodes connected to it (load) as metrics to select the default Mesh Gateway. The Mesh Gateway with the shortest hop count is selected by each HetNode. The load metric is used to select one out of multiple Mesh Gateways which might have the same hop count. The clients and the heterogeneous nodes send control messages to the Internet Gateway by including both the IP address of the LTE and Wi-Fi interfaces via LTE access technology.

Mesh Gateways maintain a routing table that lists the addresses of the HetNodes associated with it and sends update messages to the Internet Gateway when there are changes in the routing table. The routing tables in Mesh Gateways are updated using request messages from the HetNodes that try to connect to the Mesh Gateway. Each Mesh Gateway has an entry in the routing table of Internet gateway that lists all the heterogeneous nodes associated with the mesh Gateways. Further, client nodes need not support new routing tables.

The heterogeneous routing algorithm in a HetNode and the Internet Gateway, should select the

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transmission technology based on the parameters from all the network access technologies a node utilizes, and also consider the entries in the heterogeneous routing table. Routing in the WMN is left to the ad-hoc routing protocol (OLSR) which also maintains the routing tables used for routing within the mesh network.

IV. Routing Algorithm

The proposed Heterogeneous Wireless Mesh Network Routing algorithm is based on reinforcement learning and uses the Q-learning reinforcement learning algorithm as the algorithm does not require a model of the environment and is thus suited to wireless networks. Reinforcement learning algorithms evaluate past events and decisions to converge at an optimal state. Q-learning algorithm calculates reward of each action based on feedback to converge to the optimum. CHR selects the network access technology by using parameters from Wi-Fi and LTE networks and learns from previous decisions if the selected transmission technology improve performance of the heterogeneous network. The algorithm selects the transmission technology with higher Qvalue. In the uplink, CHR is used by the HetNodes to switch between LTE or Wi-Fi, and is used only by the Internet Gateway in the downlink. The original Q-learning algorithm re-computes the Q-value during a cycle to be used for decision making in the next cycle and is given as:

$$Q(t_i) = (1-\alpha)Q(t_{i-1}) + \alpha\big(R(t_i) + \gamma Q(t_{i+1}) - Q(t_{i\;\;1})\big) \qquad (1)$$

where, α is the learning rate ($0 \leqslant \alpha \leqslant 1; 0$ implies no learning), γ is defined as the discount value (=0 implies reinforcement learning is opportunistic i.e., maximizes only the immediate short-term reward) and R is the reward. Ti represents the current time or cycle and t_{i-1} represents the previous time or cycle.

CHR algorithm adopts RARE (Rate Adaptation based on Reinforcement Learning) rate control protocol operating in the MAC layer of wireless mesh networks. RARE updates the transmission rate of a node in the WMN in relation to the collision and interference in the neighboring nodes, using reinforcement learning. Thus, the transmission rate of a Wi-Fi device controlled by RARE can be used as a metric to assess the quality of the links in the WMN and the probability of successful packet transfer. The other metric used by CHR is the probability to access the channel in WMN. The Wi-Fi channel quality for node d is given as:

$$CQW^d(t_i) = RW^d(t_i)/RW_{max} \qquad (2)$$

where, RW is the transmission rate of the IEEE802.11 device.

The network parameters used by CHR to assess LTE link quality are the probability of successful transmission and the load. The load is obtained from the Radio Link Control (RLC) protocol layer in eNodeB and the HetNodes, and corresponds to the buffer length of each LTE interface and HetNodes. LTE uses separate buffers for uplink and downlink and thus the respective buffers are accessed by CHR during downlink and uplink. The LTE load on the HetNode can be obtained as:

$$LL^d(t_i) = BufL^d(t_i)/BufL_{max} \qquad (3)$$

where, BufLd is the number of packets in the LTE transmission buffer for node d and BufLmax is the maximum capacity of the buffer in terms of number of packets. Larger values of LLd (0≤LLd≤1) points to congestion at the node.

The Q-learning algorithm is adapted for WMNs using the access network parameters as:

$$QW^d(t_i) = (1-\alpha)QW^d(t_{i-1}) + \alpha\Big(SRW^d(t_{i-1}-t_i) + CQW^d(t_i) - QW^d(t_{i-1})\Big) \qquad (4)$$

where,

$$SRW^d(t_{i-1}-t_i) = STW^d(t_{i-1}-t_i)/TTW^d(t_{i-1}-t_i) \qquad (5)$$

Here, QW represents the probability of accessing the Wi- Fi channel, SRW is the success rate of node d since the last update of the transmission rate, STW is the number of successful transmissions and is obtained from the MAC layer of IEEE802.11 Wi-Fi device on HetNode by counting number of acknowledgements (ACK) received for each transmission. TTW denotes the total number of transmissions of the Wi-Fi device during the period.

The Q-learning algorithm adapted for LTE gives the probability of switching packets to LTE:

$$QL^d(t_i) = (1-\alpha)QL^d(t_{i-1}) + \alpha\Big(\big(SRL^d(t_{i-1}-t_i) + \big(1-LL^d(t_i)\big)\big) - QL^d(t_{i\;\;1})\Big) \qquad (6)$$

where, SRL is the success rate in LTE device since the last update of the probability to access LTE network and is given as:

$$SRL^d(t_{i-1}-t_i) = STL^d(t_{i-1}-t_i)/TTL^d(t_{i-1}-t_i) \qquad (7)$$

where, STL is obtained from the RLC layer using ACK and is the number of successful transmission for a node during the period using LTE network. TTL is the total number of transmissions using LTE during the period.

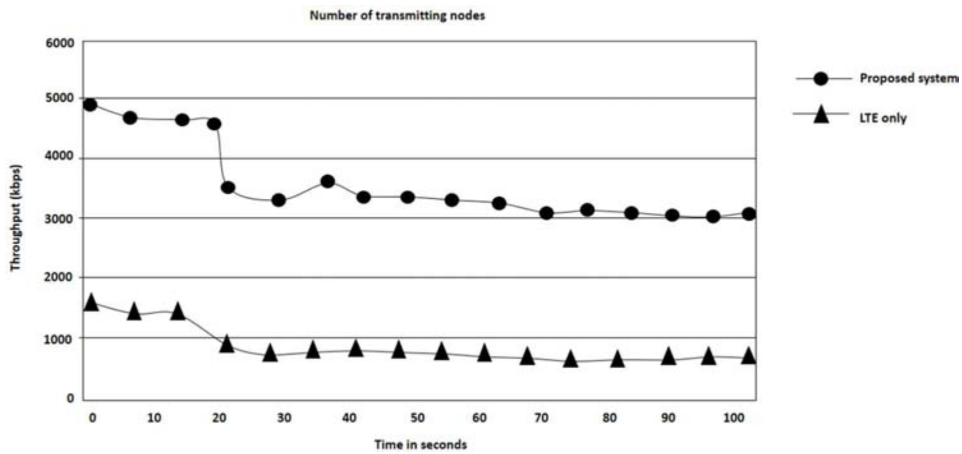

Figure 2: Throughput comparison of Proposed system with LTE-only network when 50 nodes are transmitting simultaneously

The Heterogeneous Wireless Mesh Network Routing algorithm can be divided into two stages namely exploration stage, during which the parameters are initialized, and the learning stage which keeps constant track of the parameters and evaluates previous actions to converge to the optimum and base the decision on the optimum value. During the exploration stage, a limited number of packets are transmitted through LTE and IEEE802.11s interfaces which works as a training sequence to the reinforcement learning algorithm. The influence of duration of the exploration stage on the system throughput is minimal as the algorithm converges during the cycle. The Q-learning algorithm calculates the probability of successful data transmissions of each network access technology during the learning stage and updates the Q-values. CHR then selects the interface with the higher Qvalue between the two to transmit the packets.

V. Conclusion

The heterogeneous network architecture, which integrates LTE and IEEE 802.11s, is a better solution to offload LTE traffic to unlicensed spectral bands in high density metropolitan areas. The combined virtual network makes use of heterogeneity in the network from utilizing two different network access technologies with different topologies, spectral bands etc. to improve the performance of each of the individual networks. The architecture uses LTE to prevent occurrence of island nodes in the wireless mesh network in which measures have also been taken to eliminate long multihop paths. The benefits of the underlying centralized infrastructure are utilized while providing better scalability to the network removing bottlenecks in wireless mesh networks by limiting hop count. A heterogeneous routing protocol is introduced for the purpose of the heterogeneous wireless mesh network architecture. The routing protocol performs routing table maintenance and heterogeneous routing by using parameters from the constituent networks using distributed intelligence through the use of the Q-learning algorithm. Routing within the wireless mesh network is left to the ad-hoc routing protocol. The combined network improves LTE network capacity by 2 to 3 times compared to that of the underlying individual network and also addresses issues of cell-edge network coverage among others and reduces cost of expansion of the network.

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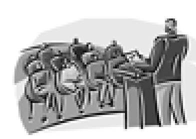

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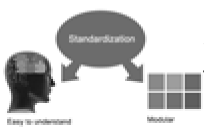

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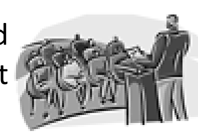

The Global Journals Incorporation (USA) at its discretion can also refer double blind peer reviewed paper at their end to the board for the verification and to get recommendation for final stage of acceptance of publication.

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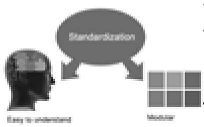
The board members can also join us as Individual Fellow with 40% discount on total fees applicable to Individual Fellow. They will be entitled to avail all the benefits as declared. Please visit Individual Fellow-sub menu of GlobalJournals.org to have more relevant details.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time. This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.



After nomination of your institution as "Institutional Fellow" and constantly functioning successfully for one year, we can consider giving recognition to your institute to function as Regional/Zonal office on our behalf.
The board can also take up the additional allied activities for betterment after our consultation.

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Note :

"

- In future, if the board feels the necessity to change any board member, the same can be done with the consent of the chairperson along with anyone board member without our approval.
- In case, the chairperson needs to be replaced then consent of 2/3rd board members are required and they are also required to jointly pass the resolution copy of which should be sent to us. In such case, it will be compulsory to obtain our approval before replacement.
- In case of "Difference of Opinion [if any]" among the Board members, our decision will be final and binding to everyone.

"

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1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript’s Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

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The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

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22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

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25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

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- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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