Analysis Of Cost Function In Medium Access Control Layer For Next Generation Wireless Terminals

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Abstract-The **next generation wireless networks impose challenges due to their architectural heterogeneity in terms of different access schemes, resource allocation techniques and Quality Of Service (QoS) requirements. These heterogeneities must be captured and handled dynamically as mobile terminals roam between different wireless architectures. These challenges are addressed by an Adaptive Medium Access Control (A-MAC) layer. This layer accomplishes the adaptively to both architectural heterogeneities and diverse QoS requirements. Based on the virtual cube concept, A-MAC provides architecture-independent decision QoS based scheduling algorithms. The virtual cube concept introduces a three-dimensional resource-space, time, rate and power. In this paper we analysis the cost. It can be introduced as (1) a function into the network-modeling framework (2) a fourth dimension in the virtual cube concept or (3) to find the switching cost between network technologies. Based on the Virtual Cube concept, A-MAC provides architecture-independent decision and QoS based scheduling algorithms for efficient multi-network access. A-MAC performs seamless medium access to multiple networks without requiring any additional modifications in the existing network structures**

Keywords: Heterogeneous wireless network, Medium access control layer, cost

I. Introduction

Next Generation (NG) wireless networks are expected to provide mobile users with a freedom of roaming between diverse set of wireless architectures. Since an NG wireless terminal will operate in these various types of networks. The Medium Access Control (MAC) layer will encounter different protocols that are already deployed in the Access Points (AP) of these networks. The various types of MAC protocols can be classified in terms of their multiple access schemes. Types of MAC protocols Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), and Carrier Signal Multiple Access with Collision Avoidance (CSMA/CA).

NG wireless terminals must provide seamless access to these networks. Also provide the mobile users with diverse set of services. NG wireless networks are also expected to provide the mobile users with diverse set of services ranging from high rate data traffics to time-constrained real-time multimedia [2]. In [7], four Quality of Service (QoS) classes are defined for Universal Mobile Telecommunication System (UMTS) networks, i.e., conversational, streaming, interactive and background. NG wireless terminals must be able to adapt to the heterogeneous access schemes.

In this paper, we aim to integrate the existing wireless architectures without requiring any modifications in the base stations. Instead, we achieve adaptivity to the architectural heterogeneity as well as diverse QoS

requirements by deploying a new adaptive MAC framework in the NG wireless terminals. The challenges addressed in this work can be summarized as follows:

A. Heterogeneity in Access Schemes

As explained before, NG wireless terminals encounter different access schemes while roaming between different wireless networks. For a seamless integration, the mobile terminal must be capable of accessing each network when needed.

B. 1.2 Heterogeneity in Resource Allocation

Each network structure performs resource allocation according to various techniques such as TDMA slots, CDMA codes, and random allocation. A metric to compare the amount of the resource allocated by different networks is required to achieve high network utilization in accessing different networks. However, there exists no such unified metric for
comparison of the allocated resources by different access schemes.

C. 1.3 Heterogeneity in QoS Requirements:

NG wireless terminals are envisioned to provide QoS guarantees according to the underlying network structures. Thus, the MAC layer must efficiently evaluate the available resources in different networks and perform access such a way that the QoS requirements of applications are satisfied.

In order to address these heterogeneities posed by the NG wireless networks, we propose a new two-layer Adaptive Medium Access Control (A-MAC). A-MAC first provides procedures for detecting and accessing the available networks that the NG wireless terminal can access, i.e., *access*. Then, the available resources in these various types of networks are modeled based on a unified resource model. Each flow that is sent to the MAC layer is then served through the network that is most suitable for the QoS requirements of the flow, i.e., *decision*.

Moreover, A-MAC provides QoS-based scheduling for multiple flows assigned to the same network, i.e., *scheduling*. As a result, the two-layer A-MAC exploits the available resources in the NG wireless networks by providing procedures for serving multiple flows through multiple network architectures available to the terminal simultaneously.

The main structure and the components of A-MAC are shown in Fig. 1. The access sub-layer is specialized for accessing the network, while the master sub-layer performs decision and scheduling of various application requests for the most efficient network. A-MAC achieves adaptivity to both the underlying network structure and the QoS requirements of different traffic types. We introduce a novel Virtual Cube concept which serves as a basis for comparison of different network structures.

Based on the Virtual Cube concept, A-MAC provides architecture-independent decision and QoS based scheduling algorithms for efficient multi-network access. Incompatibility among medium access and resource allocation techniques are melted into a unified medium access control framework, providing self-contained decision flexibility as well as capability to access various networks.

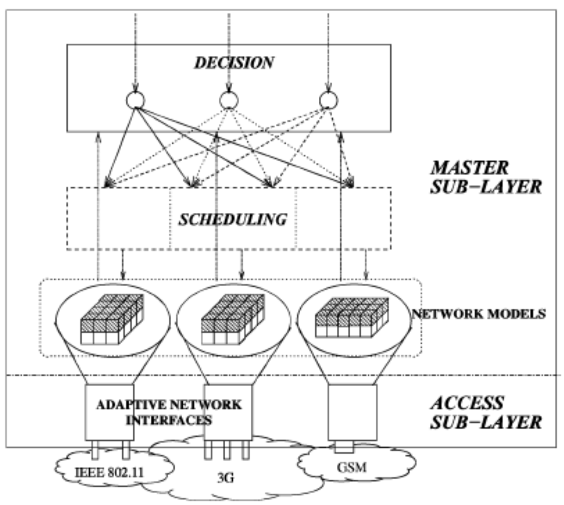

Fig. 1: Main components of A-MAC.

II. RELATED WORK

There exist several studies in the literature to address the integration of existing wireless systems. In [4], a unified framework for the channel assignment problem in time, frequency, and code domains is proposed. The unified (T/F/C) DMA algorithm consists of labeling and coloring phases. Using the graph theory solutions, channel assignment problems in heterogeneous network structures have been addressed. Although this work provides the fundamental theoretical results for channel assignment in (T/F/C) DMA networks, the framework is not applicable to the existing network structures where the channel assignment principles have already been decided.

The application of this framework requires major modifications in the NG wireless network components. An Ad-hoc CEllular NETwork (ACENET) architecture for 3.5G and 4G mobile systems is proposed in [5], where a heterogeneous MAC protocol to integrate IEEE 802.11, Blue tooth and HiperLAN/2 with cellular architectures is presented. The coordination between transmissions of different access protocols is provided using beacons from the base stations. ACENET consists of a cellular network and an ad hoc network. Although it is argued that ACENET improves the throughput performance over the existing networks, many modifications in the base stations are required to achieve this.

In [6], a TCDMA protocol is presented for NG Wireless cellular networks. However, the integration requires modifications in the existing base stations. A QoS-oriented access control for the 4G mobile multimedia CDMA communications is presented in [1]. However, the proposed protocol necessitates a new wireless network infrastructure with new base stations for Fourth Generation (4G) communications. In [3], a multiple access protocol is proposed for cellular Internet and satellite-based networks.

Although the proposed scheme is designed for both cellular and satellite networks, it requires modifications in the base station. Hence, the existing cellular networks cannot be used for integration. Analyzing the cost for heterogeneous network, several studies are made. In [8], they study how this cost affects the way nodes access the network. Intuitively, it seems that transmission costs should have a stabilizing effect as nodes will defer packet transmissions when congestion occurs and the cost for (successfully) transmitting a packet becomes high. They investigate this intuition and its implication for the design of protocols.

In [9] they consider a new class of low complexity, low power and low-cost wireless networks. Such a network typically consists of a large number of source nodes, which are within one-hop communication range to one (or a few) sink node(s). Each of these source nodes is equipped with only a transmitter module in order to eliminate the cost due to the hardware complexity and energy consumption of the receiver module.

As a result, they are not capable of receiving any signals (e.g. ACK/NAK, time synchronization beacon). The source nodes collect data and transmit a relatively small data frame to the sink node(s) once in a while and hence the throughput requirement of the source nodes is low. The sink node(s) are the only nodes in the network that are equipped with receiver modules and are capable of receiving the transmissions of the source nodes.

III. NEED FOR THE STUDY

As a result the existing system requires either a significant modification in the network structure and in the base station or a completely new architecture, which lead to integration problems in terms of implementation, costs, scalability, and backward compatibility. To integrate the existing wireless architectures without requiring any modifications in the base stations. A new adaptive MAC framework is introduced which addresses the challenges heterogeneity in access schemes, heterogeneity in resource allocation, and heterogeneity in QoS requirements.

IV. METHODOLOGY

NG mobile terminals will encounter different access schemes during accessing different networks within the NG wireless architecture as shown in Fig. 2. Hence, different resource allocation units such as CSMA random access, TDMA time slots, CDMA codes, as well as hybrid types will be allocated to the Mobile Terminals (MTs).

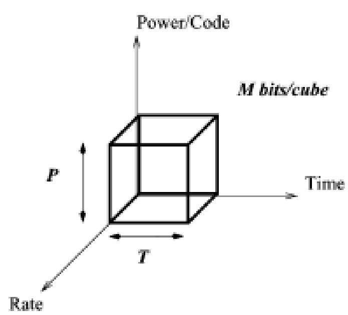

Fig. 2: Virtual Cube Structure

Thus, Mats must be able to compare these resources in order to provide QoS guarantees by accessing the most efficient network for the application. However, it is impractical to perform comparison between the resources available to the MT due to the lack of a unified metric for such comparison.

For this purpose, we introduce a three-dimensional space model for modeling network resources. Based on this three-dimensional resource-space, we propose a novel Virtual Cube concept in order to evaluate the performance of each network in the reach of an MT. The Virtual Cube concept defines a unit structure based on the resource allocation techniques used in the existing networks.

In the following two sections, we describe the resource-space model and the properties of the Virtual Cube, respectively.

A. Resource-Space

We model the resource in a three-dimensional resource-space with time, rate, and power dimensions as shown in Fig. 1 The three dimensions of the resource-space are as follows:

***Time Dimension*:** The time dimension models the time required to transfer information.

***Rate Dimension*:** The rate dimension models the data rate of the network. Thus, the capacity of different networks with the same connection durations but different data rates is captured in the rate dimension. Furthermore, the bandwidth increase due to the multi-code transmissions or multi-channel communication is also captured in this dimension.

Power Dimension: The power dimension models the energy consumed for transmitting information through the network. Note that, the resource in terms of available bandwidth can be modeled using the time and rate dimensions. However, the cost of accessing different networks varies in terms of the power consumed by the wireless terminal. Hence, a third dimension is required. Each network type requires different power levels for transmission of the MAC frames because of various modulation schemes, error coding and channel coding techniques. As a result, the resource differences in these aspects are captured in the power dimension.

The virtual cube constitutes the unit structure for modeling and comparing different networks for the appropriate access decision by the NG wireless terminal. The resource space and the virtual cube structure are shown in Fig. 2. The virtual cube structure is defined by three parameters explained as follows:

B. Virtual Cube Structure

Cube Capacity (M bits/cube:) The number of bits a cube carries. Cube Duration (T sec): The time a cube fills in time dimension. As a result, a virtual cube models a rate of bits/s in the rate dimension. Cube Power (PWatts): The minimum power for a transmission of a cube. The three parameters that define the virtual cubes, i.e., and are fixed for each cube and provide granularity in each dimension. As will be explained, the virtual cubes are used to model the available resource a network provides. In order to model both the available bandwidth and the cost of communication in terms of energy consumption, two types of virtual cubes are used in the A-MAC as described below:

Virtual Information Cube (VIC):VICs model the information sent through the network. They virtually contain bits and serve as a basis to determine the capacity of the network.

Virtual Power Cube (VPC) :The required power consumption for transmission of a bit is different for every network. VICs model the minimum power consumption required to transmit a bit by bit. In order to model the additional power consumption per bit for each network, VPC is used. VPCs model the additional power needed to transmit bits of information. As a result, VPCs, which virtually contain no data, are used to capture the additional power requirements of a particular network.

A-MAC first provides procedures for detecting and accessing the available networks that the NG wireless terminal can access - Access. Then the available resources in these various types of network are modeled based on a unified resource model. Each flow that is sent to the MAC layer is then served through the network that is most suitable for the requirements of the flow - decision. Provides QoS-based scheduling for multiple flows assigned to the same network - scheduling.

The access sub-layer is specialized for accessing the network. The master sub-layer performs decision and scheduling of various application requests for the most efficient network. Based on this three-dimensional resource-space, we propose a novel Virtual Cube concept in order to evaluate the performance of each network in the reach of an MT. The Virtual Cube concept defines a unit structure based on the resource allocation techniques.

C. Network Modeling

The Virtual Cube concept introduced in Section 4 forms a basis for modeling different access schemes. Based on the Virtual Cube concept, the underlying access schemes are modeled as a three-dimensional structure called *resource bin*.

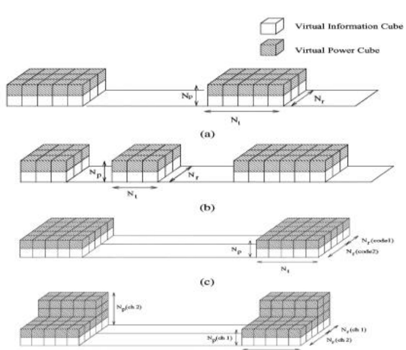

Fig. 3: (a) TDMA and CDMA modeling. (b) CSMA modeling. (c) Multi-code CDMA modeling. (d) Multi-channel modeling Each dimension of a resource bin defines the number of virtual cubes that can be filled in that dimension as shown in Fig. 3, where it is shown that VPCs, i.e., gray cubes, are used to model the additional power requirement of the network, while VICs, white cubes, model the available capacity in the network.

As a result, resource bins capture the capacity of the network access unit as well as timing information, data rate and power requirements. The modeling of TDMA, CDMA, and CSMA based networks as well as multi-rate communication into resource bins are illustrated in Fig. 3 and explained in the following sections.

TDMA Modelin:gIn TDMA systems, the channel resource is partitioned into frames. Each frame is further divided into time slots, which are assigned to different users. A TDMA slot is characterized by its slot duration T_S and transmission rate R. The slot duration, T_S specifies the duration of time the MT has the access to the TDMA network within a time frame. The transmission rate R, specifies the rate at which the MT should send packets during the time slot. Due to different modulation schemes, error coding and channel coding techniques, each interface is characterized by an average energy per bit E_b to be used during the transmission.

Using these properties, the TDMA slot can be modeled in the resource space. Let N_t, N_r, and Np be the three dimensions of a resource bin representing the number of virtual cubes that can be filled in the *time*, *rate*, and *power dimensions*, respectively.

Then, N_t, N_r, and Np can be expressed by

$$N_t = \frac{T_s}{T}, \quad N_r = \frac{TR}{M}, \quad N_p = \frac{E_b M}{P} \qquad (1)$$

where is the cube capacity, is the cube duration and is the cube power as described in Section 4. A sample model of a TDMA network is illustrated in Fig. 3(a). Note that, if the number of cubes in the power dimension exceeds one, i.e., $N_p > 1$, VPCs are filled in the power dimension.

CDMA Modeling:In the direct sequence-CDMA (DS-CDMA), each bit of duration Tc = Tb / N is coded into a pseudo-noise code of chips of duration. The pseudo-noise codes used in CDMA are characterized by the processing gain or so-called the spreading Gp gain, which is expressed as Gp = W / R, where W is the bandwidth of the CDMA system and R, is the data rate. Since each user interferes with other users at the base station in the reverse link, the base station performs power control and assigns a transmission signal power for each MT to utilize the network. The transmitted energy per bit, Eb, can be expressed as, Eb = Ps / R, where Ps is the transmitted signal power and is the data rate.

Although the physical channel is identified by a specific rate of chips, the actual bit rate of the channel varies according to the spreading factor used in coding. The MT is interested in the actual data transmission rate R rather than the channel transmission rate. The data rate of the connection is calculated according to the code assigned to the MT. Moreover, the MT is informed of the power level associated with the transmission of the signal by the base station. In TDD CDMA systems such as UMTS, the time is divided into radio frames, slots and sub-frames. Using the length of the allocated slot T_s, can be determined. In FDD systems, T_s is determined by the duration of the connection. Using this information, N_t, N_r, and N_p are determined by (1).

In CDMA networks, two nodes may lead to intracell interference when non-orthogonal codes are assigned. However, it is clear that this interference cannot be deterministically calculated before APs assign the codes to nodes and nodes start transmitting information. As a result, in A-MAC, the CDMA network is modeled based on the assignment information provided by the BSs to the adaptive network interfaces (ANIs). As a result, the effects of intracell interference are addressed by the A-MAC protocol.

CSMA Modeling:CSMA based systems such as IEEE 802.11 are characterized by the randomness in the access to the network. The mobile terminals contend for the channel using CSMA/CA. The MT that captures the medium transmits information. Hence, it is not possible to deterministically calculate the transmission time of a specific MT in CSMA based systems. In a recent work, it has been shown that in wireless networks, the past throughput value has a strong influence on the future throughput value.

Moreover, it has been found that irrespective of the velocity of wireless node, throughput prediction based on the past values is feasible. In this respect, various prediction methods can be used for predicting the connection opportunities in CSMA based network. Consequently, for CSMA-based networks, we use the last transmission information to model the resource bin as illustrated in Fig. 3(b). Based on the previous transmission information, e.g., data rate, connection time, consumed power, the dimensions of the model are determined using (1). Moreover, the generated model is dynamically modified to account for wireless medium errors and actual changes in the connection information as explained. As a result, the CSMA-based networks are modeled based on the previous connection information with adaptive updates.

V. CONCLUSION

In this proposed research the access sub-layer consists of ANIs, which performs network access. The master sub-layer coordinates incoming traffic packets and provides QoS based service. Frequent handovers between networks are prevented.

This provides a seamless medium access to multiple networks. A-MAC achieves seamless access to multiple networks, high network utilization, and meets diverse Quality of Service requirements and prevents the frequent handovers between networks.

VI. ACKNOWLEDGMENT

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