TCP/IP Suite Significant Enhancement for 4G Mobile Multimedia Internet Networks

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Abstract - The 4th Generation (4G) wireless mobile internet networks will be combined through current existing cellular networks (i.e., CDMA2000, WCDMA and TD-SCDMA) and Wi-Fi (i.e., Wireless LAN) networks with fixed internet to support wireless mobile internet as the same quality of service as fixed internet. Each of the networks has own specified protocols, disparity frequency, and maximum data speed and cost characteristics. TCP/IP suite protocols are succeeding in web application of fixed internet, but limited working on the combined networks. Two research directions are available, which are replacement and improvement. Microsoft has issued new protocol suite for replacement. In this paper, we propose a new protocol to improve TCP/IP suite protocols. This new protocol addresses limitation of TCP/IP suite so that it can work on both cellular network and Wi-Fi network simultaneously; sending data requests through cellular network and getting reply from Wi-Fi network. Ns2 Java version (Java Network Simulator) was chosen to simulate the new protocol because of its feasibility. In this paper, we present the results of our simulation.

Keywords: TCP/IP, 4G, Mobile Multimedia Networks, Wireless, Bandwidth Control, protocol design

1 INTRODUCTION

TCP/IP suite has been successful in web application in the past years especially in wired internet. The 4G networks is expected to support wireless mobile internet with the same quality of service as wired internet, especially for getting a higher data rates and utilizing bandwidth efficiently. Many research works have combined the current existing 3G networks and Wireless LAN with wired internet to reach this goal [1, 2, 3, 4]. Since 3G cellular network (i.e., CDMA2000, WCDMA) and Wi-Fi network (Wireless LAN) have different frequency, maximum data speed, and cost characteristics [5], TCP/IP suite has a limitation to work on this kind of convergence architecture.

Two kinds of solutions are available, which are replacement and improvement. Microsoft has issued MS/IP [6] as new protocol suite for replacement of TCP/IP suite. Because of superiority of TCP/IP suite protocol in web application, just few people would like to use the MS/IP suite. It seems that market is not ready to accept the MS/IP suite. An Efficient Authentication Protocol for Integrating WLAN and Cellular Networks [7] addressed the authentication problem and proposed an efficient authentication protocol to enable 3G subscribers to connect WLAN with higher data rate. The protocol focuses on improvement of the integrated networks. The TCP/IP suite works on separated network independently and performances of data rates and resources utilization are not improved yet.

This paper focuses on the improvement of TCP/IP through bandwidth disparity issue related to wireless LAN and 3G cellular networks and utilizes this kind of disparity frequency for mobile node supplying higher data rates. We propose a new protocol to combine 3G cellular network for uplink traffic services and 802.11b Wi-Fi network for downlink traffic service so that TCP/IP suite can work on both two networks simultaneously. Thus, frequency resources are efficient utilization, and we call the protocol is bandwidth optimization control protocol (BOCP). The majority of the protocol is to distribute data into both frequencies of the two networks for transmission.

We use ns2 Java version (Java Network Simulator) to simulate our system based on CDMA2000 1x-EVDO and Wireless LAN integrated networks [8]. This paper is organized as in section 1 is an introduction and section 2 is a design of protocol; in section 3, we describe the implementation and testing, and finally, section 4 is summarization and conclusion.
2 PROTOCOL DESIGN

2.1 BOCP Design

The bandwidth optimization control protocol (BOCP) is implemented in between MAC layer and TCP/IP layer. An illustrative example of the functionality of BOCP consisting of BOC (Bandwidth Optimization Control) and BOCA (Bandwidth Optimization Control Agent) components is presented in Figure 1. Packets received from higher layer are aggregated to BOC. The BOC is defined to response for generating, sending out and receiving BOCP messages and subsequently using received updates to update the relevant routing tables in our simulation model. The BOCA is a component which holds information about direct link interfaces of one node and interfaces of other nodes associated with the BOCP.

The BOC protocol works on BOC and BOCA components which will be assigned packets from higher layer to MAC layer. The basic design choices are below:
- When and where to perform packets assignment;
- Which packets are selected for assignment?

BOC generated. The BOCP messages will be sent out through the BOCA. The BOCA needs to have a list of nodes interfaces and their direct neighbors in order to generate a correct BOCP messages by BOC. Any packets that need to be sent out will be generated by the BOC. In addition, the BOC will also receive BOCP messages and subsequently using received updates to update relevant routing tables. The necessary BOCP messages are generated from PDSN in our case to all its neighbors (mobile nodes or routers) by BOC, and then dispatched to a correct destination. Actually, the BOCP passes the updates straight back to itself for routing table update, and then it passes updates to IPhandler.

2.1.2 Which packets are selected for assignment

In the BOC protocol, we consider that the selection of packets is in strict order received from higher layer. Packets from the higher layer are enqueued in order. First in First out (FIFO) algorithm is selected to ensure strict ordering. This involves an iterative operation that will first select the packet at the head of the queue for transmission preparation. Then the next packet in the queue will be selected. If the destination address of the packet is the same as the destination address of the current working frame, the packet is aggregated with the current set. This selection process iterates until condition is false. The aggregated collection of packets is then encapsulated into the WLAN frame for transmission.

2.2 BOCP Definition and Assumption

The focus of this research is on the 4G wireless mobile internet to provide data services within integrating of CDMA-WLAN network. Thus, the main system components of the CDMA-WLAN packet domain architecture are remodeled as in Figure 2. The architecture consists of the mobile node (MN), the base station (BS), the packet control function (PCF), the Packet data service node (PDSN), the access point (AP), and the packet data interworking function (PDIF).

The mobile node can be handset, laptop, personal digital assistant, etc. they can work on the full TCP/IP protocol with data/multimedia application models. The base station (BS) and the access point (AP) provide radio interface and radio link management functionality for the mobile node. And both of them provide connectivity to packet control function (PCF) and packet data interworking function (PDIF). The detailed discussion of packet control function (PCF) and packet data interworking function (PDIF) is in [10]. For PDIF, 3GPP2, the standardization
organization of CDMA2000 has specified the function of PDIF in [11].

The packet data service node (PDSN) [10] provides IP interface to the internet. For session management and radio resource management, we assume that a CDMA connection is already established under the overlapping area, and the WLAN radio resource is available for setting up a new connection.

![Figure 2: CDMA-WLAN Packet Domain Architecture](image)

### 2.2.1 BOCP Association

The BOCP association is initiated between the mobile node and the base station or the access point. A certain BOCP frame is used to initiate the BOCP association. The BOCP frame is based on the defined data frame types in [12] and conforms to IEEE 802.11 requirements. Within the MAC Header, the first two octets defined Frame Control (FC) field. The Frame Control field consists of the following subfields: Protocol Version, Type, Subtype, To DS, From DS, More Fragments, Retry, Power Management, More Data, Wired Equivalent Privacy (WEP), and Order.

In the MAC header Frame Control Field, the following items are related specifically to our BOCP protocol:

- **Type/Subtype field**: Type/Subtype fields will be used to indicate that this frame is a BOCP frame. The type field will be set to the previously reserved value (11), and the subtype (0000-1111) will be used to indicate any of the accepted data frames.
- **Duration/ID field**: Immediately following the Frame Control field in the IEEE 802.11 MAC header is the Duration/ID field. The Duration/ID field is also 16 bits in length. The contents of this field that relates to our research are as follows:

  - In control type frames of subtype Power Save (PS)-Poll, the Duration/ID field carries the association identity (AID) of the station that transmitted the frame in the 14 least significant bits (lsb), with the 2 most significant bits (msb) both set to 1. The value of the AID is in the range 1—2007.
  - In all other frames, the Duration/ID field contains a duration value as defined for each frame type. For frames transmitted during the contention-free period (CFP), the duration field is set to 32768.

Therefore, we assume that during association between the PDIF and AP, it is necessary for an association request frame to support our BOCP enhancement by setting the first 5 bits (i.e. bit from B0 to B4) of the capability information field shown in Figure 3.

This frame is transmitted to AP in order to initiate association by the PDIF. The AP will respond with an association response frame. The AP will use the same first 5 bits in the capability information field to declare its ability to support BOCP.

![Figure 3: WLAN Capability Information Field](image)

<table>
<thead>
<tr>
<th>B0</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>B5-B15</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESS</td>
<td>IBSS</td>
<td>CF Pollabl e</td>
<td>CF Poll request</td>
<td>Privacy</td>
<td>Reserve d</td>
</tr>
</tbody>
</table>

Boots: 2

#### 2.2.2 BOCP Frame Format

Our BOCP frame format is shown in Figure 4. As described in [12], the following items are specific to our BOC protocol:

- **Command field** defined message type and subtype of request or response. Type/Subtype fields will be used to indicate that this frame is a BOCP frame. The type field will be set to the previously reserved value (11), and the subtype will be used to indicate any of the accepted data frames (0000-0111), or indicating the proposed IEEE 802.11e frame (1000-1111) [13]. BOCP is compatible with either variant.

Routing Domain field will be used to indicate that mobile nodes of the routing process can be located in both WLAN and CDMA2000 domains.

Next node field is set to IP address of the next node along the way. This IP address is not necessary for destination address; it is the node neighbor’s IP address. As we mentioned in above, the necessary
BOCP messages are generated from all nodes to all their neighbors. Therefore, this field is used to indicate the mobile node neighbor’s IP address only.

Others of the frame fields are used to indicate the same functionality of [12]. Version is set to be 2. Address Family Identifier for internet networks is always 2 for IP. Route Tag provides support for EGP's [9]. Subnet Mask indicates the destination subnet mask (all 1’s for host address). Metric will be used to count node number of the special routing.

<table>
<thead>
<tr>
<th>command</th>
<th>version</th>
<th>Routing Domain</th>
<th>Address Family Identifier</th>
<th>Route Tag</th>
<th>IP Address</th>
<th>Subnet Mask</th>
<th>Next Node</th>
<th>Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(1)</td>
<td>(2)</td>
<td>(2)</td>
<td>(2)</td>
<td>(4)</td>
<td>(4)</td>
<td>(4)</td>
<td>(4)</td>
</tr>
</tbody>
</table>

Figure 4: Format of BOCP message

### 2.3 BOCP Performance Metrics

Our BOC protocol is evaluated based upon throughput and data session setup delay. We have combined the CDMA2000 and WLAN networks frequencies in order to get higher data rates, throughput and data session setup delay are two key metrics for evaluating our BOC protocol performance. These performance metrics are defined as follows:

#### 2.3.1 Throughput

The CDMA2000 network and WLAN are differing in frequency. We combined the two network frequencies through creating the BOC protocol. Throughput can be used to evaluate performance of the frequency combination. In communication networks, throughput is the amount of digital data per time unit that is delivered over a physical or logical link, or that is passing through a certain network node. For example, it may be the amount of data that is delivered to a CDMA2000 network mobile node or a WLAN network mobile node, or between the two mobile nodes. The throughput is usually measured in bits per second (bits/s or bps), occasionally in data packets per second. Relative to our research and the WLAN data link layer, throughput is defined as the total number of bits sent to the higher layer from the data link layer. The data packets received at the physical layer are sent to the higher layer if they are destined. We measured this value in terms of bits per second. Throughput represents an average rate of traffic flow where higher values are better.

#### 2.3.2 Data Session Setup Delay

As we mentioned above, we have combined the two network different frequencies through the BOC protocol assistance to establish a new connection between the CDMA2000 and WLAN networks. The new connection processing may cause data session setup delay. The data session setup delay is defined as the time between mobile nodes requesting an application service to the time when the first response packet is received. The data session setup delay is measured in seconds. The data session setup delay is used to demonstrate how the CDMA-WLAN system differed from the existing WLAN system; specifically it demonstrated the additional connection setup delay as a result of the CDMA signaling procedures.

### 2.4 Simulation Scenario

The simulation is running under the scenario termed a dual mode mobile node access CDMA-WLAN convergence architecture of CDG (CDMA develop group). The simulation model of the network is shown in Figure 5.

The primary focus of the scenario is the two access network used simultaneously for the mobile node. When the mobile node comes into the WLAN overlapping region from the CDMA2000 coverage area, the MN request will go through the first connection (MN → PDSN → CN) and the resulting reply will come through the second connection (CN → PDIF → MN). The scenario simulated a mobile node running our BOC protocol on the integrated CDMA-WLAN network. The purpose of the simulation is to exercise the integrated system over the new protocol to demonstrate system data rates.
2.5 **BOCP Simulation Design**

The rationale and design overview of the simulation-based experiments employed to evaluate the BOC protocol enhancement are contained in this section. We used JNS standard models and modified them to support our BOC protocol. The main classes such as BOC class, BOCA class, BOCPMessage class, MobileNode Class, Route Class and RoutingTable class are designed as following:

2.5.1 **BOC Class**

The BOC class is responsible for generating BOCP messages and sending them off to the correct destinations. It will also be responsible for receiving the updates ‘at the other end’ and using them to update the relevant routing table.

2.5.2 **BOCA Class**

In the network, we are interest about direct link since in BOC a mobile node send update messages to their neighbors only. Hence it is necessary to have a list of node interfaces and their direct neighbors in order to generate the correct BOC routing update messages. Therefore, the BOCA class must hold information about the interfaces associated with a particular node and keep track of what is liked to what in the network.

2.5.3 **BOCPMessage Class**

The BOCPMessage class holds the necessary information to update a MobileNode’s routing table according to BOC protocol. The class contains main information as following: the first is a mobilenode interface from and to which this BOCPMessage will be sent; the second is the simulator time at which this updated; and the third is that a vector contains BOCPMessage object references. The functionality of this class is what will be sent from a certain node to its neighbor in order to update the routing tables of the neighbor. This is the Route that will be chosen to be sent to that particular neighbor.

2.5.4 **MobileNode Class**

The MobileNode class contains a node and the interfaces associated with that node. The BOC class has a vector as an instance variable which contains references to the MobileNode object.

2.5.5 **Route Class**

The Route class holds information about which interface to send packets out on for a particular destination together with the IP address of its neighbors. This class will be modeled on the pre-existing Route class found in JNS, but will require some modification for compatibility with BOCP.

2.5.6 **RoutingTable Class**

The RoutingTable class is used to store the route objects. This class is modeled on the pre-existing RoutingTable class from JNS. The data structure of the class is hash table rather than vector. This would be more efficient when updating routes since no necessary to go through the whole routes looking for the one for updates.

3 **RESULTS**

3.1 **Throughput and available bandwidth**

Throughput is very important aspect that can determine the quality of service of wireless network for our new protocol. The simulation result shown in Figure 7 in which TCP/IP is working on both CDMA-WLAN integrated network with our proposed new protocol and CDMA2000 network. From Figure 7, the throughput is increased when TCP/IP working on integrated network because available bandwidth is much higher then TCP/IP working on CDMA2000 network alone. Furthermore, TCP/IP working on the integrated network can increase data rates more promptly then it working on CDMA2000 network since available bandwidth in WLAN network higher then in CDMA2000 network. Therefore, the proposed BOC protocol working with TCP/IP suite protocol always has a higher throughput then TCP/IP working alone on CDMA2000 network.
3.2 Data Transmission Efficiency

Figure 8 shows the relationship between available bandwidth and bandwidth waste. This relationship indicates data transmission efficiency in our proposed new protocol.

Bandwidth is the main cost paid to achieve a higher performance in our proposed new protocol, as it is able to obtain higher data rates and efficiently utilize both network resources. To evaluate this cost, we have measured data transmission efficiency. Data transmission efficiency is defined as the ratio of the number of unique application packets received to the total number of packets transmitted. From Figure 8, it is clearly shown that the bandwidth waste increase when available bandwidth increase. This is because the available bandwidth between 11 Mbps to 54 Mbps, but throughput is between 2.5 Mbps to 4 Mbps. Therefore, throughput and data rates increase as available bandwidth increase, but the data transmission efficiency is depending on many factors.

4 Conclusion and Future Work

In this paper, we proposed a new protocol called bandwidth optimization control (BOC) for combining two networks frequency in the convergence architecture. Data requests will be controlled by PCF (Packets Control Function) in CDMA2000 network and data reply will be controlled by PDIF in WLAN network. Data traffic is routed through PDSN from CDMA2000 network to WLAN network. The BOC protocol has been defined to response for generating, sending out and receiving BOCP messages and subsequently using received updates to update the relevant routing tables. The simulation results have been evaluated through throughput and data session delay parameters.

The above protocol does not consider issues such as congestion relief, re-negotiated QoS, or the movement pattern of the mobile node. In future, there is a need to develop a new detection algorithm that can support the broad level of network integration promised by the 4G wireless system.

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