Bandwidth Optimization Control Protocol for 4G Wireless Mobile Internet

Mahmoud Al-Shawabkeh, Rosli Salleh, Xichun Li
Lab of Computer System and Technology
Faculty of Computer Science and Information Technology
University of Malay, 50603, Kuala Lumpur, Malaysia

Abstract

Our proposed Bandwidth Optimization Control Protocol allows a mobile node to send request and get reply using two different networks simultaneously. Connection supply for mobile nodes is not done by modifying transport layer protocols, but by handling the update of routing table at the Internet layer using bandwidth optimization control protocol messages, options, and processes that ensure the correct delivery of request and reply. The result from our simulation shows that the mobile node is getting higher data rates and efficiently utilizes network resources as compared to using single network.

Keywords: wireless internet, 4G, bandwidth optimization control protocol, Protocols

1. Introduction

The 4G wireless systems promise to support wireless mobile internet with higher quality of service, especially for getting a higher data speed [1]. Our approach behind bandwidth optimization control protocol is through combining cellular network for uplink traffic services and 802.11b Wi-Fi network for downlink traffic service. According to a research, internet usage for uplink traffic services is one fourth of the downlink traffic services for data session [2].

4G networks is a network that merge various existing networks such as CDMA2000, Wireless LAN and WCDMA into an all IP-based network that will make the new network more powerful and stronger for mobile internet [3]. But this kind of combination may cause bandwidth disparity issue at overlapping coverage area, such as WLAN within CDMA2000 coverage area, because both of them have different frequency, maximum data speed, and cost characteristics. Our work will address this issue [4] when a mobile node comes into WLAN overlapping region from a CDMA2000 coverage area so that the mobile node can be supplied service by these two networks simultaneously.

This paper describes a new protocol based on an integration of WLAN and CDMA2000 networks and organizes as following: section 1 is introduction and section 2 is related work; in section 3, we describe components, messages and options, and algorithm of bandwidth optimization control protocol, testing and results will be described in section 4, the section 5 is numerical results, and finally, conclusion and future work is as section 6.

2. Related Work

4G application and services for a higher speed wireless internet access will be dominated by 4G wide area cellular networks and hot-spot wireless LANs, which will complement each other to provide ubiquitous high-speed wireless internet connectivity to mobile users [5]. In such environment, wireless mobile internet is anticipated to deliver service to a mobile node "anywhere at anytime with anyhow".

Currently, existing systems use their own network to provide services to mobile users. Moreover, they all have their own infrastructure. This makes it impossible for existing network systems to cooperate efficiently. Therefore, combining current wireless networks (such as WLAN and CDMA2000) is beneficial and this implementation is only possible at the higher layers of the network protocol stack, in which internetworking between the systems is based on the internet, for example based on mobile IP [6].

To combine 3G and WLAN networks efficiently is a challenging task. Many issues should be concerned, such as quality of service (QoS), seamless mobility, authentication, and so on. Particularly, the design of bandwidth optimization is critical issue.

Many works have done for improving this kind of integration. Providing QoS at the Integrated WLAN and 3G Environments [7] try to find out the best packet size and channel error rate combination for each 3G traffic classes by using different wireless and wired network when packet sizes and channel error rates are varied. An Efficient Authentication Protocol for Integrating WLAN and Cellular Networks [8] addressed the authentication problem and proposed an efficient authentication protocol to let 3G subscribers can connect WLAN with higher data rate. Both of these research works are focus on how mobile nodes can handoff to new network from current network, but no consider the overlapping case.

A new multi-path scheme for stream media was proposed in [9] which try to solve the overlapping case. In this proposed scheme, multiple paths are maintained while a mobile node transits the overlapping area of two adjacent cells, keeping connections, the proposed scheme reduces packet loss and maintains high throughput during handoffs by transmitting packets on multiple paths. Therefore, the main cost paid to achieve higher performance in the proposed scheme is the bandwidth waste due to redundant packet transmissions during the handoffs, and consider one network resource only.

We propose a new protocol to manage overlapping case and consider both networks in order to get higher data rates and utilize efficiently network resources.

3. Bandwidth Optimization Control Protocol (BOCP)

3.1. BOCP objects

Figure 1 shows the objects our proposed bandwidth optimization control protocol.

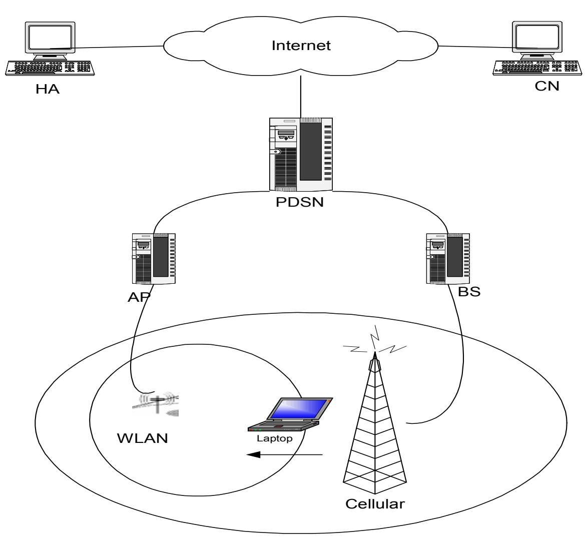

Figure1: BOCP objects

The objects of BOCP are explained as following:

- Home Agent (HA)

A router on a mobile node's home link with which the mobile node has registered its current care-of address. If the mobile node is away from home, it registers its current address with the home agent.

- Correspondent Node (CN)

A peer with whom a mobile node is communicates to. A correspondent node may be either mobile or stationary.

- PDSN

A Packet Data Serving Node (PDSN) provides access to the Internet, intranets and applications servers for mobile stations utilizing a cdma2000 Radio Access Network (RAN). Acting as an access gateway, PDSN provides simple IP and mobile IP access, foreign agent support, and packet transport for virtual private networking. It acts as a client for Authentication, Authorization, and Accounting (AAA) servers and provides mobile stations with a gateway to the IP network.

- Base Station (BS)

A base station refers to a cell, a sector within a cell, an MSC, or other part of the cellular system.

- Access Point (AP)

The function of an access point in WLANs is similar with a base station function in CDMA network.

- Mobile Node (MN)

A mobile node that can change links, and therefore addresses, and maintain reachability using its home address. A mobile node has awareness of its home address and the global address for the link to which it is attached (known as the care-of address), and indicates its home address/care-of address mapping to the home agent and Mobile IPv6-capable nodes with which it is communicating.

3.2. BOCP Header and Messages

To facilitate the sending of messages between mobile nodes and correspondent nodes, we have created a new BOCP extension header. This new header can contain one of several defined messages to perform specific functions.

3.2.1. BOCP Header

Based on internet protocol and mobile IP protocol, our new BOCP extension header is dedicated to carrying updating messages and has the structure as shown in Figure 2 and 3. The correspondent nodes use the new routing header when sending a packet directly to a mobile node to indicate the current address and next address for reply messages.

MAC header	IP header	UDP header	BOCP header	Data :::

Figure 2: The BOCP header

Payload Protocol	Header Length	MH Type	Reser -ved	Check -sum	Message Data

Figure 3: The structure of BOCP header

Within the routing extension header:

- The Payload Protocol field is always set to the value of 59 [10] to indicate that the BOCP header is the last header in the packet.
- The mobile host (MH) Type field identifies the specific type of BOCP message.
- The Message Data field contains a BOCP message.

3.2.2. BOCP Messages

The following types of BOCP messages are defined:

- Bandwidth Optimization Control Packet, it implements the messages that are sent by Bandwidth Optimization Control class. The new necessary information is added such as the current source address and the current destination address which is next destination only.
- Bandwidth Optimization Control Message, the message is sent from Corresponding Node to Packet Data Service Node (PDSN) through Bandwidth Optimization Control class. It contains information about the current source interface and the current destination interface for updating PDSN routing table according to Bandwidth Optimization Control algorithm.
- Bandwidth Discovery Request, this message is sent by correspondent node to request the current bandwidth available from a mobile node. If the mobile node receives the request, it responds with available bandwidth.
- Bandwidth Discovery Acknowledgement, this message contains available bandwidth routing including source address and destination address.

3.3. BOCP Algorithm

The BOCP components use the following algorithm when updating routing table for bandwidth optimization based on bandwidth reselection shown as Figure 4.

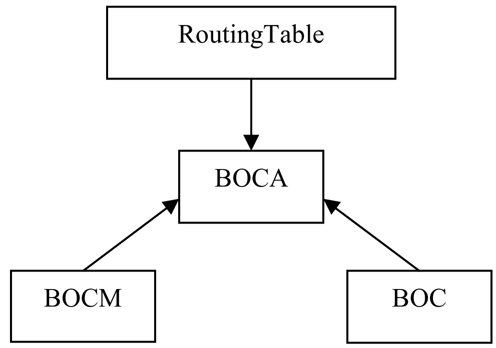

Figure 4: The Components of BOCP Algorithm

The components of Bandwidth Optimization Control algorithm are described above which including Bandwidth Optimization Control Agent (BOCA), Bandwidth Optimization Control Message (BOCM), Bandwidth Optimization Control and RoutingTable.

A mobile node uses the following algorithm to calculate available bandwidth at which access network:

1. BOCM is sent neighbor by neighbor for updating the routing table of the neighbors. It will come into BOCA firstly.
2. BOCA is a simple protocol implementation to handle new connection setup and teardown properly for providing a new data path and optimizing bandwidth when BOCM comes into BOCA.
3. BOC is a main agent in which the new protocol connects with IP. It forwards packets from BOCA to IPhandler at a certain port after BOCM comes into BOCA. This agent is located on top of IP layer.
4. The RoutingTable is updated by BOCM after BOC sending BOCM to RoutingTable from BOCA.

4. Testing and Results

To evaluate the performance of the new bandwidth optimization technique, we used Java network simulator (JNS) [11] to develop a simulation that consisted of the mobile node, the corresponding node, the home agent, and a hierarchical configuration of wireless networks.

JNS is a Java implementation of the ns-2 simulator originally from Berkeley. It allows developers of networking protocols to simulate their protocols in a controlled environment. The simulator then produces a trace file such as Figure 5.

JNS is partitioned into five packages in terms of distinctive functionality. Each package is described briefly below.

- **jns.element** – contains the static elements of the network (e.g. nodes, link, interface, etc). This package is used extensively in the BOCP protocol design in the Paper.
- **jns.agent** – contains the interfaces for agents. A new protocol to JNS has to implement one the following three interfaces: Agent, CL_Agent or CO_Agent. CO_Agent and CL_Agent extend agent class. CL means connection-less service and CO means connection-oriented service.
- **jns.trace** – provides the functionality for tracing what is going on in the network. A class turns all events into a trace file, which is then fed into *Javis*. Users can than visualise the network and networking behaviour as following Figure 5.

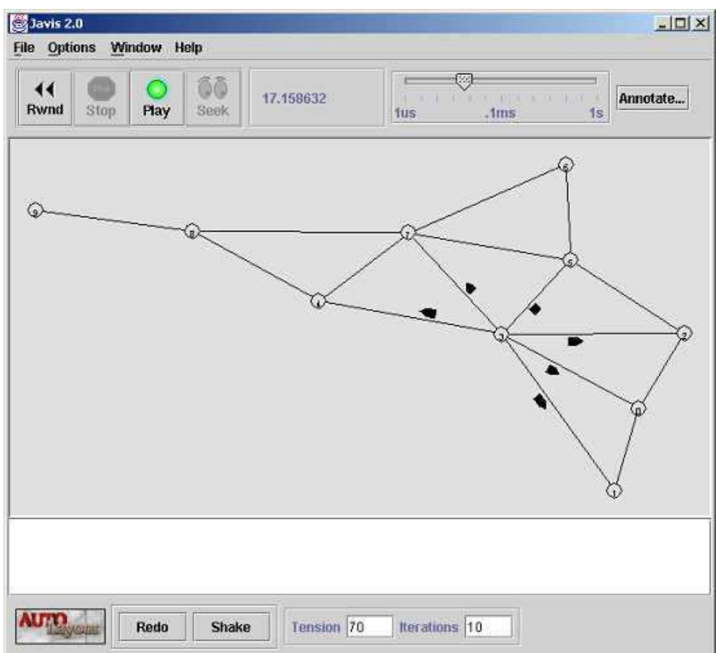

Figure 5. A simulation run from JNS displayed with Javis

- **jns.command** – contains classes used to schedule calls to functions with the simulator.
- **jns.util** – contains utility classes and tools. These include a Queue data structure, a priority queue, the IPAddr class, the RoutingTable class, the Preferences class, etc.

In this section, calculations will be made for the bandwidth use, and the data transmission efficiency.

4.1. Bandwidth Use

The total bandwidth use per connection, C_u, is defined as the total amount of resources that are expended at each connection. It can be calculated:

$$C_u = \sum_{(i,j)} C_{i,j,u}$$

$$(i,j) \in \{(CN,MN),(CN,HA),(HA,MN)\} \quad (1)$$

Where $C_{i,j,u}$ is the bandwidth used to establish node-pair (*i,j*) for the given connection. $C_{i,j,u}$ is calculated:

$$C_{i,j,u} = BW * D_{i,j,u} * (r(t_u) + \{T_d\}_{i,j,u}) \quad (2)$$

Where BW is the bandwidth allocation for the connection, and $D_{i,j,u}$ is the node distance, $r(t_u)$ is the residency time at the current connection, and $\{T_d\}_{i,j,u}$ is the time to deactivate the link at the current connection calculated in [12].

Once the number of intermediate routes is obtained, the overall bandwidth consumption, BW, could then be found by summing the bandwidth consumed by the intermediate routes for each protocol:

$$BW = \sum_{k=1}^{N_r} B_k \quad (3)$$

Where N_r is the number of possible intermediate routes and B_k is the bandwidth use for the k[th] route:

$$B_k = a_k + b_k + c_k \quad (4)$$

Where a_k is the signaling bandwidth, b_k is the wired line data bandwidth, and c_k is the wireless data bandwidth, respectively.

4.2 Signaling Delay due to the Bandwidth Optimization Procedures

To calculate the overall bandwidth optimization delay, T_h, the time to send the signaling messages for the scheme is summed as follows:

$$T_h = m * \sum_{l=L}^{N_s} T_l \quad (5)$$

Where m is the number of times a new route is determined, Ns is the number of steps (shown as Figure 2) between the first bandwidth optimization initiation and the completion of the final route, and T_l is the time to execute step l of the bandwidth optimization procedure.

The delay to deliver a signaling message M_l is:

$$M_l = (\alpha_l + \beta_l + \gamma_l) * H_l \quad (6)$$

Where α_l is the transmission time, β_l is the propagation time, and γ_l is the processing time for the control message in signaling step l. H_l is the number of hops in terms of switches involved in the signaling exchange. The transmission time is computed:

$$\alpha_l = \frac{S_l}{B_l} \quad (7)$$

Where S_l is the size of the control message in bits, and B_l is the bit rate of the link on switch the message is sent.

Using the message delivery time, M_l in (6), T_l is calculated from (5) separately for the wired line and wireless links. For the wired line links, the signaling execution time is the same as the delay message delivery time:

$$T_l = M_l \quad (8)$$

The wireless link calculation must consider the probability of wireless link failure, let n_f be the number of wireless link failures. Then for the wireless link, T_l is:

$$T_l = \sum_{n_f=0}^{N} Tn_f * \Pr ob\ (n_f \text{ is total failures}) \quad (9)$$

Let the waiting time to determine that the message is lost be equal to the time to send one message. Then T_{n_f} is

$$T_{n_f} = M_l + n_f * (2 * M_l) \quad (10)$$

And T_l becomes

$$T_l = \sum_{n_f=0}^{N} \left[M_l + n_f * (2 * M_l)\right] * \Pr ob\ (n_f \text{ Failures and 1 success}) \quad (11)$$

$$= M_l + (2 * M_l) * \sum_{n_f=0}^{N} n_f * \Pr ob\ (n_f \text{ failures and 1 success}) \quad (12)$$

Given a probability q that the wireless link fails, the techniques in [7] are used to calculate the sum in (12). Then the signaling execution time over the wireless link T_l is:

$$T_l = M_l + (2 * M_l) * \frac{q}{1-q} \quad (13)$$

Then the time to execute the signaling, T_l for each step l of the bandwidth optimization protocol is:

$$T_l = \begin{cases} M_l \\ M_l * \dfrac{1+q}{1-q} \end{cases}$$

(For the wired line links and for the wireless links, respectively) (14)

Where M_l the time to send a message and q is is the probability of wireless link failure. T_l is then used to determine the overall signaling delay for the bandwidth optimization scheme.

5. Numerical results

5.1. Throughput and available bandwidth

Throughput is one aspect that one can measure in order to determine the quality of service of the new data path scheme. Figure 6 show the throughput of the two different available bandwidth in a new cell will be used. The throughput in the proposed scheme will increase as the mobile node comes into the overlapping area served by WLAN cells when the available bandwidth in WLAN cell is higher than in CDMA2000 cell. Furthermore, the proposed scheme can increase data rate more promptly than the single path handoff scheme because WLAN has much wider available bandwidth than CDMA2000. Therefore, the proposed new data path handoff scheme always has a higher throughput than the single data path scheme.

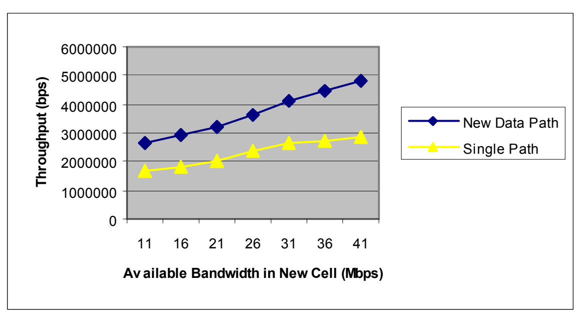

Figure 6: Throughput vs Available Bandwidth

5.2. Data Transmission Efficiency

Figure 7 shows the bandwidth waste of the two different handoff schemes as a function of the available bandwidth.

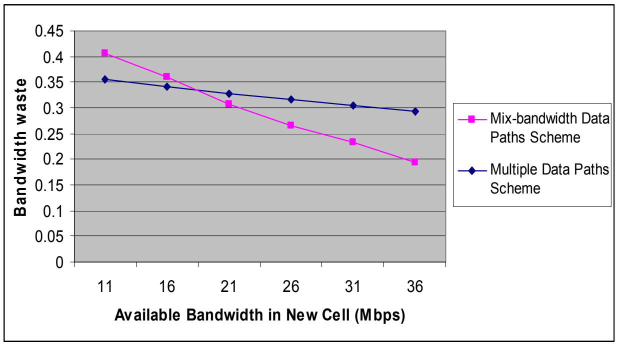

Figure 7: Data Transmission Efficiency

Bandwidth is the main cost paid to achieve a higher performance in the proposed scheme, as it is able to obtain higher data rates and efficiently utilize both network resources. To evaluate this cost, the researcher has 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 during the handoff period. Since the amount of data transmissions is mainly determined by the available bandwidth in the WLAN cells, only the available bandwidth in the proposed scheme is varied in this investigation.

6. Conclusion and future work

In this paper, we have presented Bandwidth Optimization Control protocol that can support up channel and down channel traffic services with different bandwidth and different networks by the established new data path in order to utilize bandwidth efficiency and get higher data rates. We have issued the protocol message and the algorithm. In the header of the proposed protocol, we defined current address part. It contains the next interface address which used for updating the routing table, and then gets a new data path for data transmission. Thus the two networks are together working for mobile node, and it gets higher data rates and utilizes resources efficiently.

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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