Multi-Bandwidth Data Path Design for 5G Wireless Mobile Internets

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Abstract – The 5th generation is envisaged to be a complete network for wireless mobile internet, which has the capability to offer services for accommodating the application potential requirements without suffering the quality. The ultimate goal of 5G is to design a real wireless world, that is free from obstacles of the earlier generations. This requires an integration of networks. In this paper, we propose the design of Multi-Bandwidth Data Path by integrating the current and future networks for new network architecture of 5G real wireless world. We also present our proposed architecture and results of the simulation.

Keywords: 5G, Wireless Networks, Multi-Bandwidth Data Paths, Mobile Internet

1 Introduction

Wireless mobile communication networks have been evolved for generations. The first generation (1G) wireless mobile communication network is an analog system which is used for public voice services with the speed up to 2.4kbps [1]. The second generation (2G) uses the digital technology and network infrastructure. In comparison with the first generation, the second generation supports text messaging [2]. Its success and the significant growth of demand for online information via the internet have prompted the development of cellular wireless system with the improvement on data connectivity, which is ultimately led to the third generation systems (3G).

The 3G system refers to technology standards for the next generation of mobile communications systems. The main goal of standardization efforts of 3G is to create a universal infrastructure that is able to support existing and future services [3]. This requires the design of infrastructure that it can evolves as technology changes, without compromising the existing services on the existing networks. Separation of access technology, transport technology, service technology and user application from each other make this demanding requirement possible.

The 4G mobile system is an all IP-based network system. The features of 4G may be summarized with one word—integration. The 4G systems are about seamlessly integrating different technologies and networks to satisfy increasing user demands [4, 5]. 4G technologies combine different existing and future wireless network technologies (e.g. IPv6, OFDM, MC-CDMA, LAS-CDMA and Network-LMDS) to achieve the freedom of movement and seamless roam from one technology to another as shown in Figure 1. This will enable the provision of multimedia applications to mobile users by different technologies through a continuous and always best connection possible [6, 7].

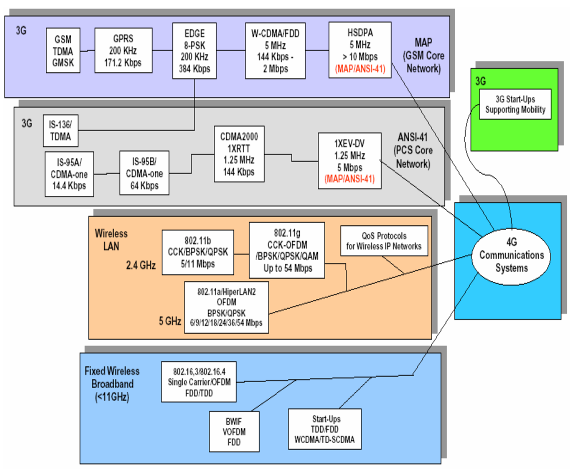

Fig. 1: 4G Technologies

The 4G networks integrate one core network with several radio access networks. A core interface is used for communication with the core network and radio access networks, and a collection of radio interfaces is used for communication with the radio access networks and mobile users. This kind of integration combines multiple radio access interfaces into a single network to provide seamless roaming/handoff and the best connected services [8].

Integrating IPv6 and multi-bandwidth data path for 5G WWWW is a challenging issue, due to the following factors – 1) the IPv6 assigns IP address on mobile nodes according to its location information, which is related with location management; 2) multi-bandwidth data path design is based on network resources efficient utilization, which is related with network resources management.

Many researches have been involved in the both issues [9, 10]. The current existing location information management techniques are classified into two categories – 1) network layer management techniques; and 2) transport layer management techniques.

The main objective of network layer location management technique is to reduce re-routing packet loss. Packets are delivered at fast speed for re-direction to new location of a mobile node. When location information changes, existing base station caches and forwards the packets to the targeted base station based on the request to forward the packets. Multiple possible locations around mobile node can receive multicast packets. Packets are routed to multiple nearby base stations around the mobile node to ensure the delivery of the packets to the mobile node; and Regional registration is completed by the foreign agent in the foreign domain [11]. In this case, re-routing packet loss is reduced by shortening the location update time for the mobile node moving within a domain. This is one typical example for a foreign agent to assign a unique regional care of address (COA) registration to a mobile node.

The transport layer location management techniques are proposed to get reliable data transmission. The main purpose of the transport layer techniques is to avoid unnecessary timeouts during location changes, but these have raised some issues as follows – 1) the first issue is intermittent disruptions in data transmission, because the technique incurs long delay to transfer the session context and to slowly start the transmission in the new wireless cell; and 2) another issue is congestion since stream transmission continues in the new cell without considering the disparity in available bandwidths.

Recently two new transport layer protocols that maintain multiple connections between the sender and the receiver have been proposed. They are stream control transport protocol (SCTP) [12] and multi-path TCP [13]. SCTP is proposed to deal with multi-homing connections for future internet. Although SCTP maintains multiple IP address as to the multi-homed destination, its current specification does not use multiple paths simultaneously but uses alternative path only to retransmit lost packets. Multi-path TCP is proposed to increase the throughput for reliable data transmission in ad hoc networks, and it achieves this goal by exploiting the aggregated bandwidth on multiple paths.

The main effort of this paper is to establish a new data path within WLAN and CDMA2000 networks by considering internet characteristics and disparity in both of the network's available bandwidth in order to get higher data rates and utilize bandwidth efficiently.

The key distinguishing factor between 3G and 4G is the data rates. 4G can support at least 100Mbps peak rates in full-mobility wide area coverage and 1Gbps in low-mobility local area coverage [14]. The speeds of 3G can be up to 2Mbps, which is much lower than the speeds of 4G. However, 4G standard will be based on broadband IP-based entirely by applying packet switching method of transmission with seamlessly access convergence [15, 16, 17, 18]. It means that the 4G integrates all of access technologies, services and applications to run unlimitedly through wireless backbone over wire-line backbone by using IP address. The 5G, on the other hands bring us to a perfect real world wireless or so-called "WWWW: World Wide Wireless Web" [19].

The idea of WWWW, World Wide Wireless Web, originates from the 4G technologies. The next evolution will be based on 4G and the completion of this idea results in the formation of a real wireless world. Thus, 5G should make a significant difference with the preceding evolution and adds more substantive services and offers a number of benefits to the world over 4G. The 5G should be featured with intelligent technology that interconnects the entire world without limits. In this paper, therefore we propose a multi-bandwidth data path scheme for 5G real wireless world, a complete WWWW.

This paper is organized as in section 1 presents an introduction and section 2 discusses the review of literature. The design of multi-bandwidth data path is presented in section 3, and we describe the implementation in section 4, and finally, section 5 is summarization and conclusions.

2 Literature Review

The 4G mobile wireless network is a research area for the next generation wireless systems, which can be supported by Bluetooth, WiFi 802.11 family, WiMax 802.16 family, cellular and satellite networks as shown in Figure 2[20]. The Bluetooth is designed for personal area, which can cover 10 meters. The WiFi 802.11 family is designed for local area, which can cover 100 meters. The WiMax is designed for metropolitan area, which can cover few kilometers. The cellular networks are designed for wide area, which can cover any where. However, 4G integrates all access networks that can provide total coverage, seamless roaming and best connected services.

Fig. 2: 4G Networks [20]

Bluetooth provides a wireless Airport (802.11b, 802.11g and 802.11n) solution for wireless networks, not a replacement for networking. On a technical level, Bluetooth is an open specification for a cutting-edge technology that enables short-range wireless connections between desktop and laptop computers and a host of other peripheral devices- on a globally available frequency band (2.4GHz) for worldwide compatibility.

The IEEE 802.11 [21] has become wireless Ethernet networking technology standard, and the products based on the standard have been made. To ensure interoperability between these products, an organization named Wi-Fi was created. The IEEE 802.11 family of WLANs has dominated through on the world.

WiMAX, the Worldwide Interoperability for Microwave Access, is a telecommunications technology aimed at providing wireless data over long distances in a variety of ways, from point-to-point links to full mobile cellular type access. It is based on the IEEE 802.16 standard, which is also called WirelessMAN. The name WiMAX was created by the WiMAX Forum, which was formed in June 2001 to promote conformance and interoperability of the standard [22]. The IEEE 802.16d stands for fixed WiMax which can not be handoff from one base station to anther and the IEEE 802.16e stands for mobile WiMax which can roam/handoff between different base stations.

The cellular networks have experienced three generation in their evolution. The 4G integrates three standards (WCDMA, CDMA and TD-SCDMA) of 3G into MC-CDMA.

Many countries have carried out projects for the development of 4G systems. The first project was undertaken by the Defense Advanced Research Projects Agency (DARPA), which is the same organization that developed the wired internet [23]. Since the distributed architecture has been so successful in the wired internet, they chose the same distributed architecture for the wireless mobile internet for 4G standards. 4G is still in laboratories, experts and policymakers have yet to agree on all the aspects of 4G wireless networks. The research community shares the common understanding of 4G: integrating (see Table1, Comparison of 3G and 4G), which integrate with IPv6, OFDM, MC-CDMA, LAS-CDMA, UWB and Network-LMDS [24].

Items	3G	4G
Speed	Up to 2Mbps	Full-mobility: up to 100Mbps Low-mobility: up to 1Gbps
Services	Difficulty of global roaming	Roaming smoothly
Core Network	Wide-area concept Circuit and packet switching	Broadband IP-based Entirely packet switching
Technologies	WCDM, CDMA2000, TD-SCDMA	All access convergence including: OFDM, MC-CDMA, LAS-CDMA, Network-LMPS

Table1: Comparison of 3G and 4G

IPv6 is a basic protocol for address issue in 4G networks. OFDM stands for orthogonal frequency Division Multiplexing, which transmitting large amounts of digital data over a radio wave. OFDM works by splitting the radio signal into multiple smaller sub-signals that are then transmitted simultaneously at different frequencies to the receiver. LAS-CDMA stands for Large Area Synchronized Code Division Multiple Access, which enables high-speed data and increases voice capacity. It is designed for global area. MS-CDMA stands for Multi-Carrier Code Division Multiple Access, which is designed for running on wide area, called macro cell. The Network-LMDS, Local Multipoint Distribution System, is the broadband wireless technology used to carry voice, data, internet and video services in 25GHz and higher spectrum. It is designed for micro cell [25].

3 Multi-Bandwidth Data Path Design

CDMA development group (CDG) has issued convergence architecture for 4G, which combined pico cell, micro cell, macro cell and global area shown in Figure 3. This architecture shows that in pico-cell area, there are four wireless network covered, in micro cell area, there are three wireless network covered, in macro cell area, there are two wireless network covered at least. The problem arises for any users at a certain place and time, it is one network supply wireless services for them, the others keep wireless network resources waste. The 5G is a real wireless world; a complete wireless communication. We design Multi-bandwidth data path for 5G so that all wireless network resource can be shared and used efficiently.

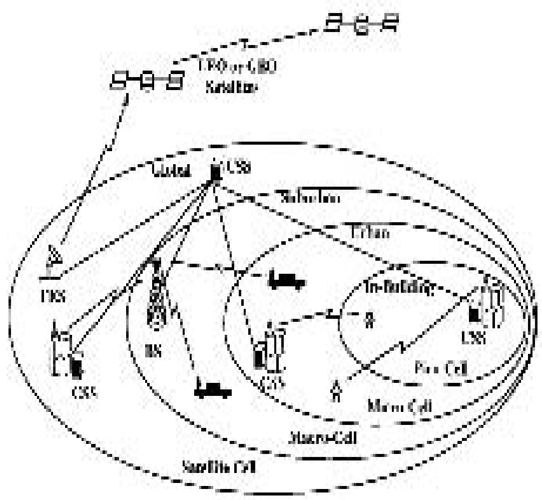

Fig. 3: 4G Convergence Architecture [26]

3.1 Multi-Bandwidth Data Path Model Design

In realizing the design of Multi-bandwidth data path, we propose a new data model as shown in Figure 4. This model is based on overlay area of any two networks. When a mobile node comes into the overlay area, both of the two networks can supply services for the mobile node simultaneously. Data request can be sent from any one network, and reply can be from any other network.

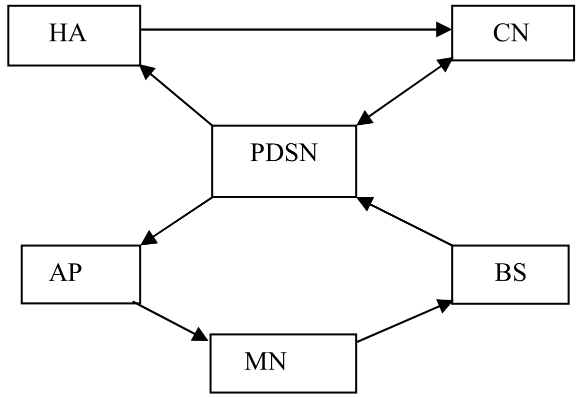

Fig. 4: Multi-bandwidth Data Path Model

Legend:
MN = Mobile Node
AP = Access Point
HA = Home Agent
CN = Corresponding Node
PDSN = Packet Data Serving Node
BS= Base Station

In this model, the request from MN is forwarded through the first connection (MN $\rightarrow$ BS $\rightarrow$ PDSN $\rightarrow$ CN) and the resulting reply is transmitted through the second connection (CN $\rightarrow$ PDSN $\rightarrow$ AP $\rightarrow$ MN). Hence, the two networks supply the services for the mobile node simultaneously. Based on the model, we propose Multi-bandwidth data path shown in Figure 5, which contains four components. They are bandwidth management, bandwidth selection, packet receiver and bandwidth monitor.

3.2 Multi-bandwidth Data Path Design

The function of bandwidth management is to install and delete bandwidth monitor components dynamically when it receives indication messages from the mobile IP protocol. The bandwidth management is located at both ends of the sender and the receiver. On each path, there is one bandwidth monitor installed. The function of bandwidth monitor is to monitor the available bandwidth and calculate the proper transmission rates on the corresponding path. The current existing path is informed by the bandwidth management after installing/deleting each bandwidth monitor. The bandwidth monitor will provide the rates information when it receives the current existing path information from bandwidth management. The function of the bandwidth selection is to calculate and report encoding rates to encoder, and then IPv6 applications will be encoded to appropriate paths. The packets receiver accepts incoming packets from the bandwidth monitor, filters and reorders them before sending them to the decoder. A detailed description on each of these four modules is given in the following sub-sections.

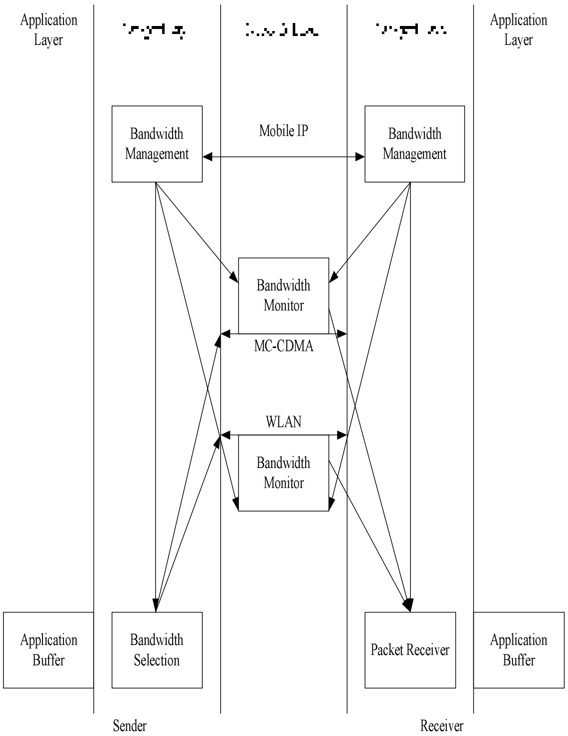

Fig. 5: Multi-bandwidth Data Path Architecture

3.2.1 Bandwidth Management

We assume that any two networks are WLAN and CDMA2000. WLAN is used to cover small area, and CDMA2000 covers wide area. Both of them have differences in bandwidth, data rates and cost. Therefore, bandwidth management component is needed for implementing the selection of bandwidth in the Multi-bandwidth data path architecture. During the bandwidth selection, the bandwidth management will perform the following two operations:

Firstly, the bandwidth management installs bandwidth monitor for the new bandwidth path, and then it sends a RATE_READY message to the local sender/receiver to indicate the existence of new bandwidth when mobile IP reports a new location with PATH_ADD message;

The bandwidth management will delete the bandwidth monitor and send a RATE_DEL message to the local sender/receiver to indicate that an existing bandwidth is lost when the mobile IP reports a loss of new location with PATH_LOSS message.

Both types of bandwidth indication messages contain a unique PATH_ID to identify the bandwidth to a mobile node. To allow a sender to be able to maintain two bandwidths simultaneously, mobile IP simultaneous binding and route optimization options are used.

3.2.2 Bandwidth Selection

Bandwidth selection is located at the sender side only. Since WLAN has integrated into CDMA2000 networks, the message exchange is between both networks i.e., from the sender to the receiver. In this case, the bandwidth selection will calculate and report the encoding rates to the encoder so that it can adapt its encoding rates accordingly after the selection of bandwidth receive the bandwidth existence information from the bandwidth management and the rate information from the bandwidth monitor. The bandwidth selection is also responsible for assigning bandwidth encoded IPv6 application.

3.2.3 Bandwidth Monitor

As stated earlier that the function of bandwidth monitor is to calculate the proper transmission rates and monitor packet flows on the corresponding path. The bandwidth monitor is located at both the sender and the receiver on each bandwidth path which is installed by the bandwidth management. The data transmission rate is calculated by certain algorithm. From the theoretical point, a lot of rate control algorithm can be used in this proposed architecture to calculate data rates. However, we has selected TCP friendly rate control (TFRC) algorithm [27] for the bandwidth monitor. During data rates calculation, bandwidth monitor at the sender periodically exchanges TFRC rate control information with the corresponding bandwidth monitor at the receiver. Both the sender and the receiver reports are exchanged between the sender and the receiver. In this case, the sender generates a report to update the rate control information and the receiver generates a report too for the controlled path in order to observe congestion status to the sender. The rate control information of the report includes the path ID so that it can be directed to the corresponding bandwidth monitor which is inherited from the TFRC definition.

3.2.4 Packets Receiver

Packets receiver is located at the receiver side only. The function of packets receiver is to buffer and reorder all the packets received from both bandwidth monitor. It is further to filter out the redundant packets before delivering them to the target application.

4 Results

The Multi-bandwidth data path system design is based on the following two ideas. First, multi-bandwidth data path is supported by any two different networks simultaneously, which can work on a mobile node. Second, bandwidth optimization is possible through bandwidth reselection, which makes rerouting from one network to another when a mobile node gets reply from its corresponding node.

The above two ideas are extracted from the characteristics of internet application and clearly that its application requests bandwidth is less than the reply bandwidth [28].

4.1 System Implementation

The system implementation involves two phases – 1) IPv6 message exchanges for establishing a new data path; and 2) data transmission on the established new path.

In the first phase, when a mobile node comes into WLAN overlapping region from a MC-CDMA coverage area, it sends requests through MC-CDMA and gets reply for higher data rates from WLAN networks. The second phase, after the new multi-bandwidth data path is established, internet session will be transmitted on the data path.

4.2 Simulation Parameters

In order to investigate the impact of integration of IPv6 and Multi-bandwidth within MC-CDMA and WLAN convergence architecture, the following network parameters are compared to the old scheme.

i. Throughput and Available bandwidth; and
ii. Data transmission efficiency from sender to receiver.

In this simulation, we calculate the available bandwidth in a wireless cell by the link speed minus the volume of background traffic generated in the wireless cell [29]. Owing to the packet encapsulation overhead and the control overhead to the MAC layer, the actual throughput is much lower than the available bandwidth. In this experiment, the actual throughput is around 100Mbps with the available bandwidth of 5Gbps, and 1Gbps with the available bandwidth of 25bps [30]. In the simulation, the available bandwidth in a wireless cell is varied from 5Gbps to 25Gbps. In the set of simulation experiments, the default value of round trip time is 60ms.

4.3 Performance Metrics

The special issues in the integration of IPv6 and Multi-bandwidth data path scheme are buffer requirement and bandwidth recalculation. When IPv6 packets come down to network layer from allocation layer, the packets have to do bandwidth reselection between WLAN and MC-CDMA. This reselection will be based on bandwidth calculation which has been done by bandwidth monitor component. After the calculation, the result then transfers to bandwidth management so that IPv6 packets can make a choice. During these procedures, the IPv6 packets have to be queued in the buffer of sender. After these packets received by packets receiver, all of them have to be queued in buffer of receiver for filtering and recombining.

4.4 System Testing

The performance of the integration is evaluated through extensive simulation using ns2 Java version-Java Network Simulator (JNS) [31]. The objective of the simulation is two-fold:

i. To verify that the IPv6 works on the Multi-bandwidth properly; and
ii. To investigate the impact of various network parameters on the performance of the integration.

To evaluate the performance of the integration, we have developed a simulation that consists of the mobile node (MN), the corresponding node (CN), the packet data service node (PDSN) and the packet data interworking function (PDIF) as shown in Figure 6. The original design is IPv6 packet sends request though MN to PDSN and finally arrives in CN; the reply should be from CN to PDIF and finally arrives in MN. Therefore, there are two items that need to be verified through out this testing as follows:

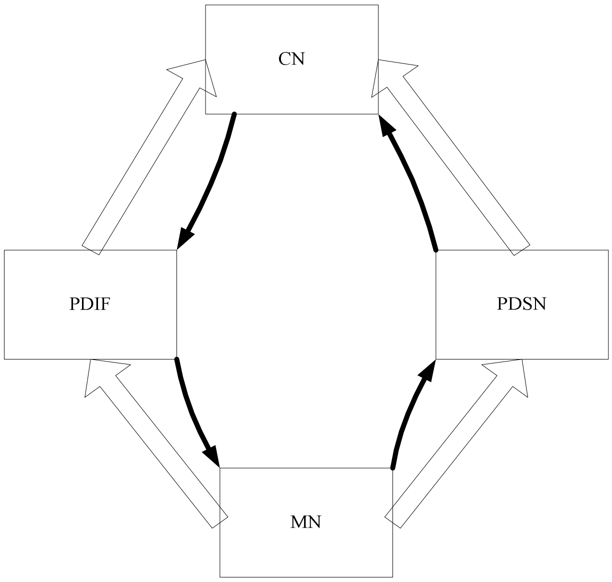

Fig. 6: Simulation Scenario Model

4.4.1 Integrating Test for IPv6 and Multi-bandwidth

This test verifies the interoperation after the integration of IPv6 and Multi-bandwidth. A simple network with four nodes has been established for this test (see Figure 6). We set the default values of "call attempt" and "call accepted" are "0", after the testing, the values of "call attempt" and "call accepted" become "1". The testing result shows that IPv6 can send packet through Multi-bandwidth in Figure 7.

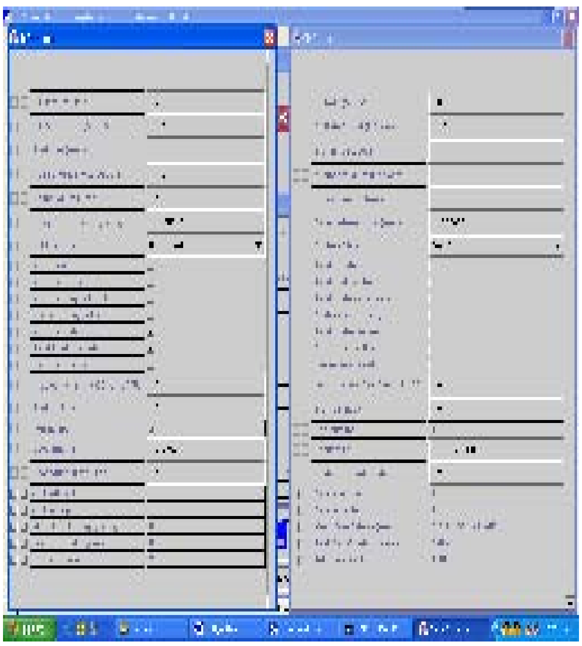

Fig. 7: IPv6 sends packet on Multi-bandwidth

4.4.2 Data transmission Test

This test verifies the data transition on the integration system that can be done properly between two mobile nodes. In the Figure 7, the bottom items are "total packet send" and "total packet receive", the amount of "total packet send" is "316" and the amount of "total packet receive" is "1269". The relationship of the two values shows that the "total packet send" is one fourth of the "total packet receive". From Lucent research, the internet application bandwidth request is one fourth of the reply [2]. This relationship just indicates that data transmission on the integration of IPv6 and Multi-bandwidth.

4.5 System evaluation

We evaluate the system implementation from two sections as follows:

i. Message exchanges for establishing new data path; and
ii. Data transmission on the established new path.

In the first case, when a mobile node comes into WLAN overlapping region from a CDMA2000 coverage area, it sends requests for better services from WLAN. In our simulation system, the values of "calls attempted" and "calls accepted" are assigned "1", which shows that there is one Multi-bandwidth data path established between WLAN and CDMA2000 networks for the mobile node. In the second case, we connect the values of total packets which sent from both of MN request and CN reply. The value of MN requests is much less than the values of CN replies.

4.6 Throughput and available bandwidth

Throughput is very important aspect that determines the quality of service of wireless network for our proposed new scheme. Figure 7 shows the simulation result in which TCP/IP is working on both CDMA-WLAN integrated network with our proposed Multi-bandwidth data path and CDMA2000 network. From Figure 8, 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.

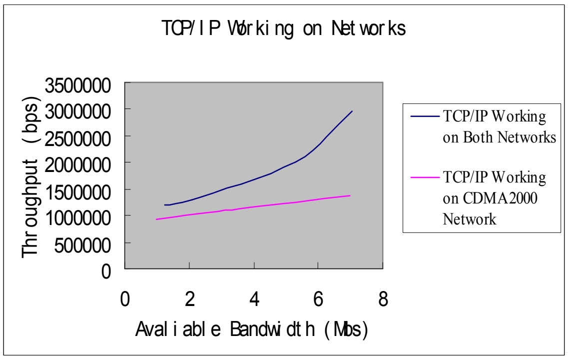

Fig. 8: Throughput vs Available Bandwidth

4.7 Data Transmission Efficiency

The Figure 9 shows the relationship between available bandwidth and bandwidth waste. This relationship indicates data transmission efficiency in our proposed new Multi-bandwidth data path scheme.

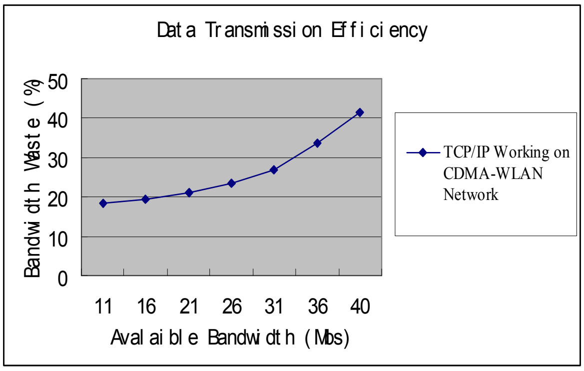

Fig. 9: Data Transmission Efficiency

Bandwidth is the main cost to achieve a higher performance in our proposed new protocol. 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 Figure4, 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 rats increase as available bandwidth increase, but the data transmission efficiency is depending on many factors.

5 Performance Analysis

According to the prediction for 4G in [19], the available bandwidth is ranging from 5Gbps to 25Gbps, which is enough wide for mobile user. Thus, for the performance analysis we focused on buffer requirement and numerical results.

5.1 Buffer Requirement Analysis

According to ITU (International Telecommunication Unit) standards, for a non-real-time internet session, the buffer time, B_t, is defined as the length of time that the packets are released from the existing route to a new route which is established and this is calculated as follows [3]:

$$B_t = R_{i(CN, MN)} \quad (1)$$

During the course of the simulation, the IPv6 packets were transmitting from CN to MN, using the any two nodes distances by the packets rate to calculate the buffer time for the IPv6 packets which is from CN to MN. In the formula above, one can denote the buffer time as $R_{t(CN, MN)}$ which is shown in (1). This represents the time that the controlled-load traffic is buffered by CN. Then, the required buffer size, B_s, is calculated as follows:

$$B_s = B_t * P_r \quad (2)$$

$$P_r = b_r * P_s \quad (3)$$

From the formula, the buffer size (B_s) is equal to buffer time (B_t) times with packet rate (P_r), and the packet rate (P_r) is equal to bit rate (b_r) times with the packet size (P_s). Thus, we can get buffer size (B_s) as follows:

$$B_s = B_t * b_r * P_s \quad (4)$$

5.2 Numerical Results

Figure 10 shows the requirements of buffer size in the integration of IPv6 and Multi-bandwidth. As the number of internet reselection session increased, the buffer size requirement is increased. This is because in formula (4) above, the buffer size is depending on three factors: buffer time (B_t), bit rate (b_r) and the packet size (P_s). In the simulation system, the buffer time depends on the distance of the two nodes, but it is fixed, no any changes. The packet size (P_s) should be same in whole simulation. Thus, the buffer size (B_s) depends on bit rates (b_r). On the other hand, Figure 10 also shows that the buffer requirements are same whatever with bandwidth reselection or without bandwidth reselection. This is because that there are same numbers of active data sessions applying for buffer spaces in both cases.

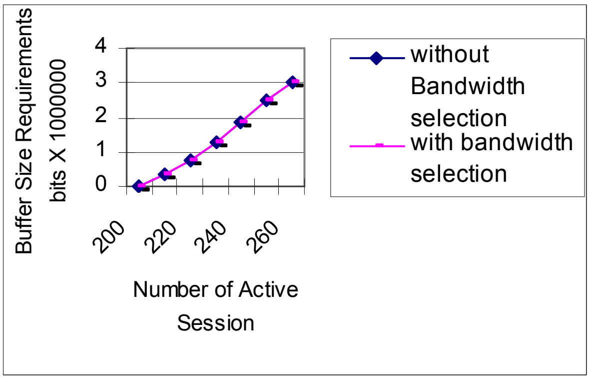

Fig. 10: Buffer Size Requirements

6 Conclusion and future work

In this paper, we proposed Multi-bandwidth data path scheme for 5G real wireless world. Data requests will be controlled by PCF (Packets Control Function) in the CDMA2000 network and data reply will be controlled by PDIF (Packet Data Interworking Function) in WLAN. Data traffic is routed through PDSN from CDMA2000 network to WLAN network. The Multi-bandwidth data path scheme has been defined to do bandwidth reselection for rerouting so that all network resources can be used efficiently.

The new Multi-bandwidth data path scheme does not consider issues such as congestion relief, re-negotiated QoS, or the movement pattern of the mobile node. In the future, there is a need to develop a new detection algorithm that can support the broad level of network integration promised by the 5G wireless system.

References

[1] S. Y. Hui and K. H. Yeung, “Challenges in the migration to 4G mobile systems”. IEEE Communications, vol. 41, No. 12, Dec. 2003.

[2] Lucent technologies, “Wireless Network Systems-3G Engineering Guidelines”. June 2001.

[3] Al-Shawabkeh, M; Salleh, Rosli; Li, Xichun, (2007) “Bandwidth optimization control protocol for 4G wireless mobile internet”, Proceedings of the 11th WSEAS International Conference on Communications, Vol. 3, pp. 279-284. July 23-25, 2007. Agios Nikolaos, Greece.

[4] http://grouper.ieee.org/groups/802/11/. (Accessed by January 2008).

[5] J. Pereira. “The Path to 4G” in Wireless, Mobile and Always Best Connected. DVD Proc. of the 1st International ANWIRE Workshop. Glasgow, Scotland. ISBN 0-9545660-0-9. April 2003.

[6] Abdullah Gani, Xichun Li, Lian Yang, Omar Zakaria, (2008) “TCP/IP Suite Significant Enhancement for 4G Mobile Multimedia Internet Networks”, Proceedings of the 8th WSEAS International Conference on Multimedia System and Signal Processing (MUSP ’08). Vol. 586, pp. 229-235. April 6-8, 2008. Hangzhou, China.

[7] Yuh-Min Tseng', Chou-Chen Yang' and Jiann-Haur Su, “An Efficient Authentication Protocol for Integrating WLAN and Cellular Networks". Project supported by National Science Council, under contract no. NSC92-22 13-E-018-014.

[8] 3GPP2, “CDMA2000 WLAN Interworking”, S.R0087-Av1.0, Mar. 2006.

[9] 3GPP2, “CDMA2000 Wireless IP Network Standard”, X.S0011-D v1.0, Mar. 2006.

[10] 3GPP2, “Access to Operator Service and Mobility for WLAN Interworking”, X.P0028-200 v0.2, Mar. 2006.

[11] J. Fakatselis, “802.11e draft standard d1.0 letter ballot 27 comments, general,” IEEE 802.11-01/2673, dated 5 October 2001.

[12] V. Cerf, R. Kahn, “A Protocol for Packet Network Intercommunication”, IEEE Trans. on Comm., COM-22(5), May 1974.

[13] W. Zhao and M. Ammar and E. Zegura, “Controlling the Mobility of Multiple Data Transport Ferries in a Delay-Tolerant Network,” in IEEE INFOCOM, Miami, FL, March 2005.

[14] Rosli Salleh, Xichun Li, Lina Yang, Zhiyuan Li, (2008), “Radio Frequency Convergence Protocol for 4G Networks”, Proceedings of the 8th WSEAS International Conference on Multimedia System and Signal Processing (MUSP ’08). Vol. 586, pp. 287-293. April 6-8, 2008. Hangzhou, China.

[15] M. Buddhikot et al., “Integration of 802.11 and Third Generation Wireless Data Networks”, IEEE INFOCOM 2003, Apr. 2003.

[16] R. Chandra, P. Bahl, and P. Bahl, “MultiNet: Connecting to Multiple IEEE 802.11 Networks Using a Single Wireless Card,” in IEEE INFOCOM, Hong Kong, March 2004.

[17] Wei Song, Hai Jiang, Weihua Zhuang, Xuemin Shen, “Resource Management for QoS Support in Cellular/WLAN Interworking”, pp. 12-18, IEEE Network, Volume 19, 2005.

[18] K. Fall, “A Delay-Tolerant Network Architecture for Challenged Internets,” in ACM SIGCOMM, Karlsruhe, Germany, August 2003.

[19]. Xichun Li, Abdullah Gani, Lina Yang, Omar Zakaria, Badrul Jumaat, “Mix-Bandwidth Data Path Design for 5G Real Wireless World”. The Proceeding of WSEAS 13th International Conferences on Multimedia and

Communication, Crete Island,Greece, 21-23,July 2008. pp.216-221.
[20]. Chen, YP; Yang, YH (2007), “A new 4G architecture providing multimode terminals always best connected services”, IEEE Wireless Communications, Volume: 14 Issue: 2 pp. 36-41.
[21]. 3GPP (2002). Feasibility study on 3GPP system to Wireless Local Area Network (WLAN) interworking (Release 6). 3GPP, TR 22.934 V6.1.0. http://www.3gpp.org/ftp/Specs/2002-12/Rel-6/22_series/22934-610.zip.
[22]. Rissen, JP (2008), “Mapping the wireless technology migration path: The evolution to 4G systems”, Enriching Communications, Volume: 2 Issue: 1 pp. 73-79.
[23] V. Srivastava and M. Motani, “Cross-layer design: a survey and the road ahead,” IEEE Communications, vol. 43, no. 12, pp. 112–119, 2005.
[24]. Xichun Li, Rosli Salleh, (2007), “Handoff techniques for 4G wireless mobile Internet”, Information Technology Journal 6 (5), pp. 745-750.
[25] Shenoy, N. Montalvo, R. “A Framework for Seamless Roaming across Cellular and Wireless Local Area Networks”, pp. 50-57, IEEE Wireless Communications Volume 12, 2005.
[26]. Chen, HH; Guizani, M; Mohr, W (2007), “Evolution toward 4G wireless networking”, IEEE Network, Volume: 21 Issue: 1 pp. 4-5.
[27]. Frattasi, S; Gimmler, A (2008), “Potentials and limits of cooperation in wireless communications: Toward 4G wireless”, IEEE Technology and Society Magazine, Volume: 27 Issue: 1 pp. 8-12.
[28] Hyang Duck Cho, Wooshik Kim, "A Seamless Handover between CDMA2000 and WLAN for 3G-WLAN Interworking Service Continuity," AICT-SAPIR-ELETE, pp. 261-66, Advanced Industrial Conference on Telecommunications
(AICT/SAPIR/ELETE'05), 2005.
[29] Seong Soo Park, “Design and performance evaluation of roaming service base on MIP in heterogeneous network”, pp. 908-922, 10th Asia-Pacific Conference on Communications and 5th International Symposium on Multi-Dimensional Mobile Communications Volume 2, 2004.
[30]. Ruscelli, AL; Cecchetti, G (2008), “Toward the QoS support in 4G wireless systems”, proceeding of 18th Tyrrhenian Workshop on Digital Communications, pp. 245-252. September, 2007 Italy.
[31]. http://jns.sourceforge.net/ (Accessed by January 2008).