Radio Frequency Combination for TCP/IP Suite Protocol Improvement in 4G Mobile Internet Networks

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Abstract: - In this paper, we present our new proposed protocol to enhance the TCP/IP versatility as the main protocol for wireless data transmission. TCP/IP has shown its superiority in the selection of protocol for establishing wired networks. Unfortunately, its superiority cannot be extended to wireless networks. However, we believe that the integration of several types of networks would take place. The 4th Generation (4G) wireless mobile internet networks will merge the current existing cellular networks (i.e., CDMA2000, WCDMA and TD_SCDMA) and Wi-Fi networks (i.e., Wireless LAN) with the fixed internet to support wireless mobile internet. This integration would provide the same quality of service as fixed internet. Each of the networks has their own specified protocols, disparity frequency, and maximum data speed and cost characteristics. TCP/IP suite protocols were successful in web application of fixed internet, but exhibit limitation to work on the combined networks. Two research directions are available, which are replacement and improvement. Microsoft has issued a new protocol suite for replacement. In this paper, we propose a new protocol to improve TCP/IP suite protocols. This new protocol addresses the 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 and discussion of our simulation.

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

I. INTRODUCTION

The 4G networks are expected to support wireless mobile internet with the same quality of service as wired internet. In order to reach this goal, cellular networks and wireless LAN have to be integrated with wired internet network. Cellular networks have experienced three generation of changes [1]. The first generation is an analogy system which is used for voice service only; the second generation is based on digital technology which had resulted in cell phones and network infrastructure. As a means of communication, the second generation supports text messaging as well as voice. It has been successful in text messaging but due to higher demand for online information via the Internet, it prompted the development of cellular wireless systems with improved data connectivity, which ultimately lead to the latest third generation (3G) systems.

3G wireless refers to the wireless communication protocols that supports voice, text messages and data transmission. All these capabilities are defined in the standard that has been developed for the next generation of mobile communications systems. One of the main goals of the standardization efforts of 3G is to create a universal infrastructure that is able to support internet services. This requires the infrastructure to be designed so that it can facilitate the changes of technology, without jeopardizing the existing services on the existing networks. Separation of access technology, transport technology, service technology and user applications from each other make this demanding requirement possible [2].

3G cellular network (i.e., CDMA2000, WCDMA) and Wi-Fi network (Wireless LAN) have different frequency, maximum data speed, and cost characteristics [5]. WLAN bandwidth is much wider than 3G cellular networks which coverage is much wider than WLAN. Obviously, it is advantage for 4G networks to integrate the two networks to supply services to mobile users. Actually, many research works have integrated the two networks [3, 4]. The problem is TCP/IP suite can not work on the integrated architecture.

TCP/IP suite has been successful in web application in the past years especially in wired internet. The 4G networks can run the web application with the same quality of service as wired internet. This requires the TCP/IP to work on the integrated architecture, which motivated us to do the research [5]. Thus, the objective of the paper is to present our work on obtaining higher data rates and efficient utilization of bandwidth in the 4G networks.

Two kinds of solutions are available, which are replacement and improvement. Microsoft has issued MS/IP [6] as a new protocol suite for replacement of TCP/IP suite. Because of TCP/IP suite has been successful in web application, just few people are in

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favour to use the MS/IP suite. The rest remains sceptical about its advantages. It seems that market was 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 the bandwidth disparity issue that related to wireless LAN and 3G cellular networks, and utilizes this kind of disparity frequency for mobile node supplying higher data rates [29, 30]. We propose a new protocol that combines 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, the frequency resources are efficiently utilized, and we called the protocol as radio frequency combination protocol (RFCP). The main function of the protocols is used 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 the CDMA2000 1x-EVDO and Wireless LAN integrated networks [8].

This paper is organized as section 1 is an introduction and section 2 presents related work to provide an insight on the subject matter. A design of protocol is presented in section 3. We describe the implementation and testing in section 4, and finally, section 5 is summarization and conclusions.

II. RELATED WORKS

This paper is based on the work of integrating WLAN and CDMA2000 networks. In order to provide better insight, this section presents a basic theoretical background of 3G wireless cellular networks and the wireless LAN technologies.

The exponential growth of Internet and the proliferation of cellular mobile systems and WLAN systems throughout both home and business applications generated both competition and cooperation among the different systems [9, 10, and 26]. In the near future, multimedia applications which are mainly achieved by wired and fixed internet users will be achieved by mobile internet users as well. To achieve this kind of advance level of mobile wireless multimedia services it requires the network and WLAN network to be integrated in order to provide these emerging services [11, 27]. Academic researchers and service providers have worked on ways to integrate the WLAN systems with mobile cellular systems and fixed Internet [30]. The desire was to gain the increased data rates provided by WLAN working together with the mobility provided by cellular systems. This research effort focuses on frequency combination and TCP/IP suite protocol enhancement to improve performance for data transmission.

4G wireless mobile internet networks will integrate current existing cellular networks and WLAN networks with fixed internet network. CDMA Develop Group (CDG) has issued the convergence architecture [12]. IEEE 802.11b and 802.11g are operating at 2.4GHz frequency band. They can support a maximum data rate of 11Mb/s and 54Mb/s respectively [13]. Another standard i.e. IEEE 802.11a can offer a maximum data rate of 54Mb/s operating at 5GHz frequency band. For local area coverage, these technologies can achieve a higher data rate at a very low cost and therefore are now widely implemented in hotels, restaurants, shopping malls, homes etc. On the other hand, for a wide area coverage, the CDMA2000 network is widely implemented but with moderate data rate. For example, CDMA2000 1xEV-DO Release A can provide only up to 3.1Mb/s in downlink and 1.8Mb/s in uplink [14]. These two networks are incompatible but allowing these networks to complement each other is an advantage. The possible solution is to optimize the network usage by allowing mobile devices full access to both networks simultaneously. The issues in convergence these two networks have been addressed by the CDMA Development Group (CDG) [15]. Following the convergence architecture, in this research, the targeted network environment is an infrastructure-based wireless network within WLAN and CDMA2000 cell overlapping areas to allow mobile nodes to connect to multiple neighbouring base stations and access points simultaneously.

Since the current TCP/IP suite protocols work on one network independently, it has limitation to work on two or more networks. This limitation is due to the nature of routing protocols which prohibits message passing through different networks. For example, in the WLAN-CDMA2000 integrated system, TCP/IP suite protocol can only work on WLAN or CDMA2000 network, but it cannot work on WLAN and CDMA2000 networks. Therefore, the first phase of our research was motivated by the need to have TCP/IP suite protocol that capable of working on the integrated CDMA2000 and WLAN systems [16, 28].

It seems that services and applications via different access networks and technologies will be the driving forces for future developments to maximize the use of the available spectrum. Therefore, the second phase of this research is motivated by the desire to improve data rates over the WLAN-CDMA2000 integrated system. This research considers the frequency disparity of CDMA2000 1.25Mbs channels and WLAN 11Mbs channels. We combine the two frequencies so that mobile node can send requests through CDMA2000 channels and get reply through WLAN channels.

The above two motivations had inspired us to propose a new protocol. The new protocol design is presented as follows.

III. PROTOCOL DESIGN

A. *RFCP Design*

The Radio Frequency Combination Protocol (RFCP) is implemented in between MAC layer and TCP/IP layer. An illustrative example of the functionality of RFCP consisting of RFC (Radio Frequency Combination) and RFCA (Radio Frequency Combination Agent) components is presented in Figure1. Packets received from higher layer are aggregated to RFC.

The Radio Frequency Combination (RFC) is a function to generate, send out and receive RFCP messages and subsequently using the received messages to update the relevant routing tables in our simulation model. The RFCA is a component which holds information about direct link interfaces of one node and interfaces of other nodes associated with the RFCP.

The RFC protocol comprises of RFC and RFCA components which will be assigned packets from the higher layer to the MAC layer. The basic design questions are as follows:

- When and where to perform packets assignment;
- Which packets are selected for assignment?

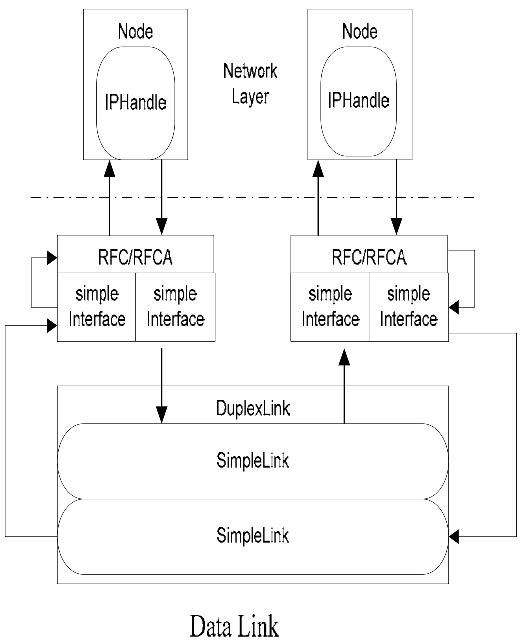

Fig. 1 RFC Protocol Overview

1. *When And Where To Perform Packets Assignment*

The above Figure 1 illustrates the processing of packets which are coming from the higher layer. The Figure shows that the RFCA includes direct links interfaces which are used to send out RFCP messages after the RFC has generated the message. The RFCP messages will be sent out through the RFCA. The RFCA needs to have a list of nodes interfaces and their direct neighbours in order to generate a correct RFCP messages. Any packets that need to be sent out will be generated by the RFC. In addition, the RFC will also received RFCP messages and subsequently using received message to update the relevant routing tables. The necessary RFCP messages are generated from Packet Data Service Node (PDSN) and in our case to all its neighbours (mobile nodes or routers), and then dispatched to the correct destination. Actually, the RFC passes the updates straight back to itself for routing table update, and then it passes updates to IPhandler.

2. *Which Packets Are Selected For Assignment?*

In the RFC protocol, we consider that the selection of packets is in strict order upon receiving the packets from the higher layer. Packets from the higher layer are enqueued in order, using First in First out (FIFO) algorithm. It was 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.

B. *RFCP Definition and Assumption*

The focus of this research is on the 4G wireless mobile internet to provide data services within the integration of CDMA-WLAN networks. Thus, the main system components of the CDMA-WLAN packet domain architecture are remodelled as in Figure2. 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).

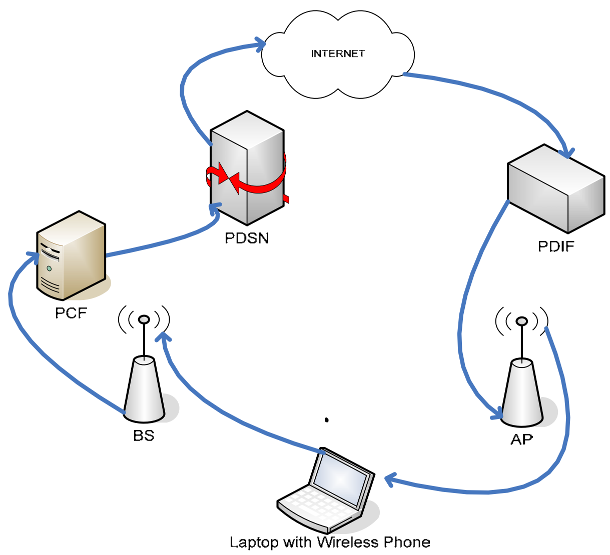

Fig. 2 CDMA-WLAN Packet Domain Architecture

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) is in [17, 24]. For PDIF, 3GPP2, the standardization organization of CDMA2000 has specified the function of PDIF in [18].

The packet data service node (PDSN) [19, 25] 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.

1. RFCP Association

The RFCP association is initiated between the mobile node and the base station or the access point. A certain RFCP frame is used to initiate the RFCP association. The RFCP frame is based on the defined data frame types in [20, 26] 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 RFCP protocol:

Type/Subtype field: Type/Subtype fields will be used to indicate that this frame is a RFCP 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 RFCP 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 RFCP.

B0	B1	B2	B3	B4	B5-B15
ESS	IBSS	CF Polla-ble	CF Poll request	Priv-acy	Reser-ved
Octets: 2					

Fig. 3 WLAN Capability Information Field [20]

2. RFCP Frame Format

Our RFCP frame format is shown in Figure 4. As described in [20], the following items are specific to our RFC 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 RFCP 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) [18, 21]. RFCP 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 neighbour's IP address. As we mentioned in above, the necessary RFCP messages are generated from all nodes to all their neighbours. Therefore, this field is used to indicate the mobile node neighbour's IP address only.

command (1)	version (1)	Routing Domain (2)
Address Family Identifier (2)		Route Tag (2)
IP Address (4)		
Subnet Mask (4)		
Next Node (4)		
Metric (4)		

20 bytes

Fig. 4 Format of RFCP message

Others of the frame fields are used to indicate the same functionality of [20, 23]. Version is set to be 2. Address Family Identifier for internet networks is always 2 for IP. Route Tag provides support for EGPs [22]. 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.

C. RFCP Performance Metrics

Our RFC protocol was evaluated based on throughput and data session setup delay. We combined the CDMA2000 and WLAN networks frequencies to get higher data rates. Throughput and data session setup delay are two key metrics for evaluating our RFC protocol performance. These performance metrics are defined as follows:

1. Throughput

The CDMA2000 network and WLAN are differing in frequency. We combined the two network frequencies through creating the RFC 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. Data Session Setup Delay

As we mentioned above, we have combined the two network different frequencies through the RFC 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 signalling procedures.

D . Simulation Scenario

The simulation was running under the scenario defined as 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.

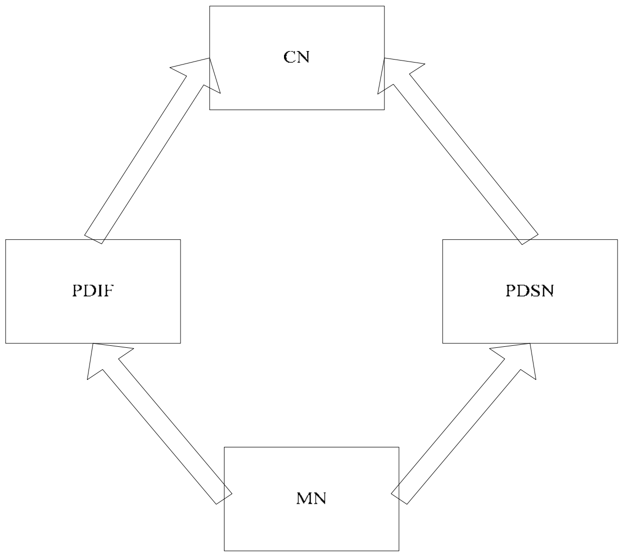

Fig. 5 Simulation Scenario Model

The main 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 $\rightarrow$ PDSN $\rightarrow$ CN) and the resulting reply will come through the second connection (CN $\rightarrow$ PDIF $\rightarrow$ MN). The scenario simulated a mobile node running our RFC 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.

1. RFCP Simulation Design

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

a. RFC Class

The RFC class is responsible for generating RFCP 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.

b. RFCA Class

In the simulation network, we only interested about the direct link since in the RFCP a mobile node sends update messages to their neighbours only. Hence it is necessary to have a list of node interfaces and their direct neighbours in order to generate the correct RFCP routing update messages. Therefore, the RFCA class must hold information about the interfaces associated with a particular node and keep track of what is liked to what in the network.

c. RFCP Message Class

The RFCP Message class holds the necessary information to update a Mobile Node's routing table according to RFC protocol. The class contains main information as following: the first is a mobile node interface from and to which this RFCP Message will be sent; the second is the simulator time at which this updated; and the third is that a vector contains RFCP Message object references. The functionality of this class is what will be sent from a certain node to its neighbour in order to update the routing tables of the neighbour. This is the Route that will be chosen to be sent to that particular neighbour.

d. Mobile Node Class

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

e. 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 neighbours. This class will be modelled on the pre-existing Route class found in JNS, but will require some modification for compatibility with RFCP.

f. *Routing Table Class*

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

IV. SIMULATION, IMPLEMENTATION AND TESTING

After the RFC protocol design and the simulation design, the next step was to look at some of the code of JNS to get a basic idea about how the program was implemented. This was followed by setting up internetwork in JNS and visualizing them with JVS to see whether it has been set up correctly. Therefore, this section will present the implementation of our proposal design and the tests that were carried out.

As for simulating the implementation environment, we select ns2 Java version network simulator. The Java Network simulator (JNS) is chosen due to its flexibility and extensive model library sets. Furthermore, the JNS allows developers of networking protocols to simulate their protocols in a controlled environment. JNS then produces a trace file (same format as NAM trace files) which can be viewed in a network animator such as Javis [8].

The main class in JNS is the Simulator class. It contains the main loop that will update the elements of the network. In addition, four packages related with our research are included in the simulator shown in Table 4-1 as following:

JNS Packages	Description
Element	In JNS implementation environment, basic networks can be built by instantiating classes in the Element package
Command	Contains instances of element, such as Node, Interface and Link. Command object must contain the simulator time at which that event should be carried out
Agent	All objects making use of protocols to send packets must implement agent
Utilize	The utilize package contains classes like the IPAddr class and Preferences class for setting preferences like the maximum transmission unit to be used in a particular simulation run

Table 4-1: JNS overview

Decisions about what to implement for this system would be quite ambitious. Initially, the aim is to implement a stand-alone version using the RFC protocol algorithm to update routing tables and, once this is established to be working correctly, RFCPMessage will be sent from one node to another. After this basic implementation has been accomplished, it can be extended to include request messages with responses and triggered updates. This implementation would also be expected to be able to cope with links in the internetwork.

The requirement for this system implementation is to be able to send RFCPMessage within the convergence architecture after the routing table updated by the generated updates. It is therefore necessary to be able to distinguish mobile nodes for the RFCPMessage. Since these updates are variable, different routes can be used to send the RFCPMessages to different neighbors according to the RFC strategies.

The above implementation requirements revealed the need for five main classes. The first and the most important class would be the class responsible for generating updates, sending them out, receiving updates and updating routing tables. This class is called the RFC class. Another important class is the class which holds all the information about the links in the network, i.e. the RFCA class. The other three classes are also required to represent routes, routing tables and the update messages that get to be sent out; the Route, RoutingTable and RIPMessage classes, respectively.

Our novel contributions are the ideas to combine radio frequency within CDMA2000-WLAN convergence architecture through the suggestion of the RFC protocol for 4G mobile internet networks. The RFC protocol design has been presented in previous section. The next sub-section will explain the implementation of RFC protocol. The purpose of the implementation is to verify the proposed new protocol on how it works on the JNS system.

A. Implementation

Our implementation consists of the classes as presented in Table 1. The RFC class is the core class which will be implemented in the essential algorithm associated with our proposed RFCP. The relationships between the Simulator class and the element package of JNS and the classes associated with RFCP are illustrated as follows.

The first step for the simulation is to update the element of the network by the Simulator class. The Simulator class is the main class in the JNS, it contains main loop which can update the elements of the network. The RFCA class is the first class which runs in the simulation. During the RFCA class implementation, the network information is

Main Class Name	Description
Simulator	• The main JNS class • Contains instances of element • Will call the first RFCA class • Initialize the internal network structure and implementations
RFCA	• Contains instances of element, such as Node, Interface and Link • The RFCA class holds all information of the network, which used to send messages out • Updating its neighbor link information • Getting a reference from the JNS simulator class
RFCPMessage	• Contains Route • Contains interface from and interface to • Two kind of the RFCPMessages: Request and Response
RoutingTable	• Contains all of possible routes in each node
Route	• Supplied to RFCPMessage class • Supplied to RoutingTable class
RFC	• Generating RFCPMessage • Generating its updates • Sending messages • Receiving messages

Table 1: Implementation Classes

generated in the RFCA object, its neighbor link information is updated and a reference to the RFCA object will be obtained from the Simulator class. Meanwhile, the RFCA class requires having its own commands which is scheduled to be executed at a specific time. Every Command object contain the simulator time. The Command object is then scheduled by placing it in the simulator event queue. After that, the core RFC class is to be run. In this stage, the RFC object generates updates for the RoutingTable. After the RoutingTable is updated, the new route is generated. When this implementation is finished, the new route information is transmitted to through the RFC object. The RFCA class updates its neighbor link information once received the new route, then the RFCPMessage send to its correct destination through the RFCA object.

In order to make the system works, we need to make sure that it is capable of performing the following tasks:

- Store network information. This is to complete by the RFCA object. During the implementation in this stage, the RFCA object is to store the network information, which is to be used to select a route and add the route into the RFCPMessage.
- The RFCPMessage. This object contains route information.
- Selecting a route for the RFCPMessage. This is to be completed by the RoutingTable object. All of possible routes are included in to the object, and the suitable route for the RFCPMessage is to be selected.
- Adding the route for the RFCPMessage. This is to be completed by the Route object. Once the suitable route established, the route is to be added into the RFCPMessage.
- Updating the routing table. This is to be completed by the RFC object.

B. Testing

The RFC Protocol testing was carried out to verify the original design expectation. The original design idea was to create a new protocol for being able to update the CDMA2000-WLAN convergence network routing table so that data message can be sent through CDMA2000 network and reply through WLAN network. In this regard, two main tests are presented in this section. One is to verify the new protocol whether it works on the convergence network properly, and the other is on the routing table whether it is updated or not. If all of the expectation of the original design idea can be obtained from the system correctly, the system output should show the information. For example, if the RFC protocol works on the system correctly and the RFCPMessage are sent on the system, this information should present in generated file.

In order to carry out the test, it is necessary to configure Java Network Simulator. Once all the code for the Java Network Simulator and Visualizor has been copied, the CLASSPATH needs to be set. The whole directory structure from this directory downwards can be copied as well. After saving the changes and logged out, we are now ready to run the Java Network Simulator to do our testing. The detailed testing is discussed in the following sections.

After testing the environment configuration, a bottom-up testing methodology has been adopted, whereby all the methods in each class that is written are systematically tested. These tests and their results will not be shown through visualizor. The final class to be written is the RFC class. When testing the updating of routing table, it could be seen that the rigorous testing involved up associated with the RFC class.

The following section presents the result of the experiments. There are three items have been verified through out this testing as follows:

- The integrating test for the RFC protocol and the JNS simulator. This testing is to verify that the RFC protocol can work on the JNS properly. The results should show the RFCP in the generated file.
- The RFCP packet testing. RFCP is a new protocol that we design to update the CDMA2000-WLAN convergence network routing table so that the RFCPMessage can be sent through both of CDMA2000 and WLAN networks. If the RFCPMessage can be delivered properly, the results should show data transmitting requests through CDMA2000 network and reply through WLAN network.
- The RFC protocol testing. This testing is to verify that whether the RFC class generates the RFCPUpdates and updates its routing table. After the updates are successful, the network information is shown in generated files.

C. Result Analysis

1. Throughput

Throughput is very important parameter that determines the quality of service of wireless network. The simulation result as shown in Figure 6 has helped us to conclude that the TCP/IP works on both CDMA-WLAN integrated network with our new proposed protocol and CDMA2000 network. Figure 6 illustrates that the throughput is increased when TCP/IP working on integrated network because the 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 is working on CDMA2000 network since available bandwidth in WLAN network higher then in CDMA2000 network. Therefore, the proposed RFC protocol works with the TCP/IP suite protocol and it always has a higher throughput then TCP/IP working alone on CDMA2000 network.

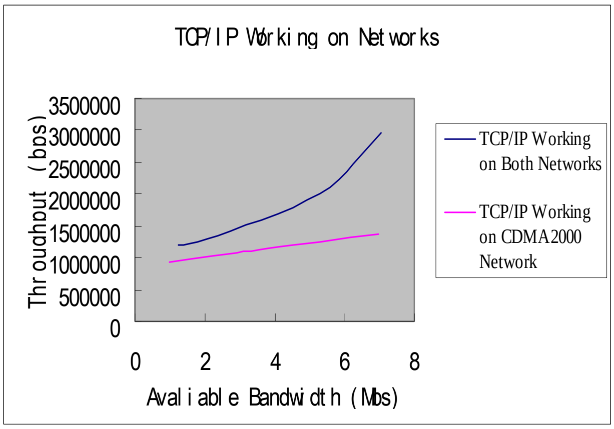

Fig. 6 Throughput vs Available Bandwidth

2. Data Transmission Efficiency

Figure 7 shows the relationship between available bandwidth and bandwidth waste. This relationship indicates the efficiency of data transmission in our proposed protocol.

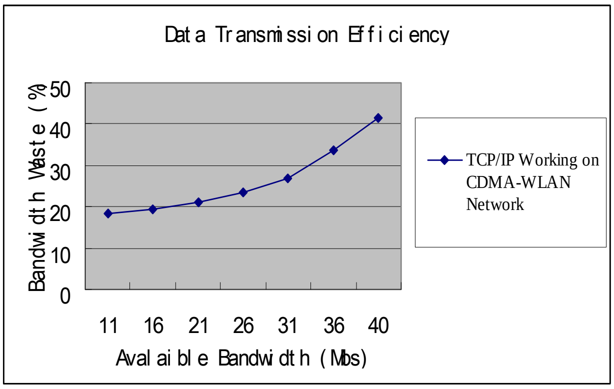

Fig. 7 Data Transmission Efficiency

Bandwidth is the main cost to achieve the higher performance in our new proposed protocol. The higher bandwidth can obtain higher data rates and utilize efficiently both the network resources. To evaluate this cost, we have to measure 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 rate increase as available bandwidth increase, but the data transmission efficiency is depending on many factors.

V. CONCLUSION AND FUTURE WORKS

In this paper, we proposed a new protocol called Radio Frequency Combination (RFC) for combining two network frequencies in the convergence architecture. The requests for data requests are controlled by PCF (Packets Control Function) in CDMA2000 network and the reply of data are controlled by PDIF in WLAN network. The data traffic is routed through PDSN from CDMA2000 network to WLAN network. The RFC protocol has been defined to response for generating, sending out and receiving RFCP 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.

However, the above protocol does not consider the issues of congestion relief, re-negotiated QoS, or the movement pattern of the mobile node. In the future, there will be 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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