Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 9 (2): 334-340, 2009
ISSN 1812-5654

Wireless Spectrum Combination Protocol for 4G Networks

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Abstract: This research studies on multimedia applications which are now mainly achieved by wired and fixed internet users will also be widely achieved by mobile internet users in 4G networks as well. 3GPP2 has proposed a solution through integrating CDMA2000 network and WLAN network with fixed internet network for the issue. This kind of integration does not consider the wireless spectrum disparity and utilize them efficiently to get higher data rates for mobile internet users. In this study, we propose a new protocol to combine the two networks wireless spectrum. In the end, we simulate and quantitatively demonstrate the new protocol performance.

Key words: Multimedia, protocol, mobile internet, 4G

INTRODUCTION

The exponential growth of the 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 (Frattasi and Gimmler, 2008). In the near future, multimedia applications which are now mainly achieved by wired and fixed internet users will also be widely achieved by mobile internet users as well. To achieve this kind of advance level of mobile wireless multimedia services require the development of the internet, cellular communication network and WLAN network to be integrated to provide these merging services (Xichun and Salleh, 2007). Academic researchers and service providers have both thought ways to integrate the WLAN systems with mobile cellular systems and fixed Internet. The desire was to gain the increased data rates provided by WLAN working together with the mobility provided by cellular systems. This research effort focused on wireless spectrum combination for 4G mobile internet networks.

The expectation for 4th generation wireless mobile internet networks is to support wireless mobile internet with the same quality of service as wired internet, especially for getting a higher data rates and utilizing wireless spectrum efficiently (Rissen, 2008). Thus, 4G is an evolution not only to move beyond the limitations and problems of 3G, but also to enhance the quality of services, to increase the bandwidth and to reduce the cost of the resource. Many researches have combined current existing 3G networks and Wireless LAN with wired internet to reach this goal (Zhenan *et al*., 2006; Peng and Wang, 2008). Since 3G cellular networks have wider coverage but lower data rates, WLAN has higher data rates but smaller coverage, this kind of integration allows mobile users fully handoff from CDMA 2000 network into WLAN network in order to get higher data rates. The problem is that mobile users to be served only by WLAN network and the CDMA 2000 network wireless spectrum wasted.

Seamless services and applications via different access networks and technologies that maximize the use of available wireless spectrum will be the driving forces for future developments (Ruscelli and Cecchetti, 2008). Therefore, this research is motivated by the desire to improve data rates over the WLAN-CDMA2000 integrated system. We consider the wireless spectrum disparity of CDMA 2000 1.25 Mbs channels and WLAN 11 Mbs channels. This research combines the two kind of spectrums so that mobile node can send requests through CDMA 2000 channels and get reply through WLAN channels.

This study focuses on data transmission regarding the wireless spectrum disparity issue of wireless LAN and 3G cellular networks and utilizes this kind of disparity spectrum for mobile node supplying higher data rates. We propose a new protocol to combine 3G cellular network for uplink traffic services and 802.11b Wi-Fi network for downlink traffic service so that TCP/IP suite can work on networks simultaneously. Thus, wireless spectrum resources are efficient utilization and we call the protocol

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is wireless spectrum combination protocol (WSCP). The majority of the protocol is to distribute data into two wireless networks for transmission.

We have chosen ns2 Java version (Java Network Simulator) to develop the system based on CDMA 2000 and Wireless LAN integrated networks. Wireless LAN is working on IEEE 802.11 standards. IEEE 802.11b and 802.11 g are operating in 2.4 GHz frequency band. They can support a maximum data rate of 11 and 54 Mb sec^{-1}, respectively. Another standard i.e., IEEE 802.11a can offer a maximum data rate of 54 Mb sec^{-1} operating in 5 GHz 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 CDMA 2000 network is widely implemented but with moderate data rate. For example, CDMA 2000 can provide only up to 3.1 Mb sec^{-1} in downlink and 1.8 Mb sec^{-1} in uplink (3GPP2, X.S0011, 2002). These two networks are incompatible but allowing these networks to complement each other is an added advantage. Possible solution that we have proposed is to optimize the network usage by allowing mobile devices full access to both networks simultaneously. Issues in integrating these two networks have been addressed by the 3GPP2. Following the integrated architecture, in this research, the targeted network environment is an infrastructure-based wireless network within WLAN and CDMA 2000 cell overlapping areas to allow mobile nodes to connect to multiple neighboring base stations and access points simultaneously.

Other studies related to our research including multimode protocol for 4G networks (Berlemann *et al.*, 2006) and QoS based handoff for CDMA 2000-WLAN interworking (Zhenan *et al.*, 2006).

3GPP2, a standard organization, has issued the integrated architecture for WLAN and CDMA networks. This kind of integration has given a solution to improve the coverage and data rates through WLAN and CDMA 2000 network characteristics. But it caused interworking problem which makes data transmitted on the integrated architecture difficult. On the other words, data transmitted on the integrated architecture independently by one of the two networks and another network has not supply any services for mobile users. In the integrated architecture, the researchers have not given a solution about the interworking problem.

In the multimode protocol research, efficient multimode protocol architecture for complementary radio interfaces in relay-based 4G networks has been proposed (Berlemann *et al.*, 2006). The article presented a protocol reference architecture that enables the efficient integration of multiple modes in a complementary way, which facilitates the coexistence and cooperation of different modes in all mode nodes of future wireless mobile internet networks. But the researchers have not considered the Quality of Services (QoS) for the given solution.

The research of QoS based handoff for CDMA 2000-WLAN interworking has been proposed. The researchers have proposed a solution when mobile users come into the overlapping area, which the mobile users fully handoff from CDMA 2000 network into WLAN.

Obviously, these researches are the significant contributions for 4G networks and will benefit mobile users. But none has been considered the wireless spectrum wasted in the overlapping case under integrated architecture of WLAN and CDMA networks. In this study, we will propose a solution for the overlapping case problem, which can utilize the wireless spectrum efficiently and get higher data rates as the following section.

MATERIALS AND METHODS

WSCP design: The Wireless Spectrum Combination protocol (WSCP) is implemented in between MAC layer and TCP/IP layer. An illustrative example of the functionality of WSCP consisting of WSC (Wireless Spectrum Combination) and WSCA (Wireless Spectrum Combination Agent) components is presented in Fig. 1. Packets received from higher layer are aggregated to WSC. The WSC is defined to response for generating, sending out and receiving WSCP messages and subsequently using received updates to update the relevant routing tables in the simulation model. The WSCA is a component which holds information about direct link interfaces of one node and interfaces of other nodes associated with the WSCP.

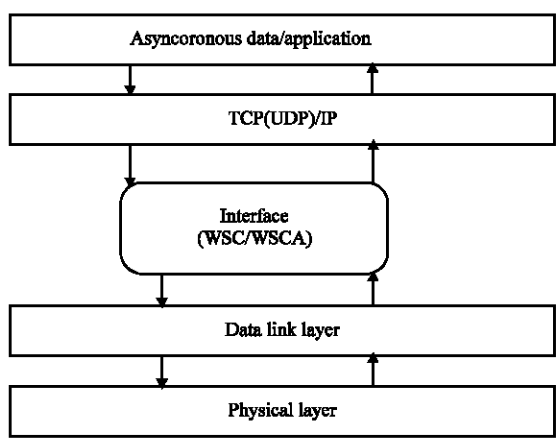

Fig. 1: WSCP overview

The WSCP works on WSC and WSCA components which will be assigned packets from higher layer to MAC layer. The basic design choices are below:

* When and where to perform packets assignment
* Which packets are selected for assignment

WSCP packets selection and assignment: Figure 2 shows the processing of packets from the network layer to data link layer for transmission. The processing includes packets selection and assignment.

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

After the packet selected, it will be assigned to interface for sending out. In the Fig. 2, it shows that the WSCA has a direct link interface which is used to send WSCP messages after the messages generated by WSC. The WSCP messages will be sent through the WSCA. In order to do this, the WSCA needs to have a list of nodes interfaces and their direct neighbors so that it can generate a correct WSCP message. Any packets that need to be sent out will be generated by the WSC. In addition, the WSC will also received WSCP messages and subsequently using received updates to update relevant routing tables. Thus, the necessary WSCP messages are generated by WSC and then dispatched them to a correct destination.

WSCP definition and assumption: The WSCP is implemented using Java Network Simulator (ns2 java version). The Java Network Simulator (JNS) allows developer of networking protocols to simulate their protocols in a controlled environment. Several assumptions are necessary to limit the scope of present research. The intent of these limiting assumptions is to keep the simulation complexity manageable, while still meeting the research goals.

The focus of this research is the 4G wireless mobile internet to provide data services inside the integrated CDMA-WLAN network. Therefore, the voice service, circuit switched domain is not considered. Thus, the main system components of the CDMA-WLAN packet domain architecture are remodeled as in Fig. 3. The architecture consists of the mobile node (MN), the Base Station (BS), the Packet Control Function (PCF), the Packet Data Service Node (PDSN), the Access Point (AP) and the Packet Data Interworking Function (PDIF).

The mobile node can be a handset, a laptop, a personal digital assistant, etc. we assume that these devices can have full TCP/IP protocol support with data and multimedia application running.

The Base Station (BS) and the Access Point (AP) provide radio interface and radio link management functionality for the mobile node. These devices provide connectivity to Packet Control Function (PCF) and Packet Data Interworking Function (PDIF), respectively.

The Packet Data Service Node (PDSN) provides IP interface to the internet. For session management and radio resource management, we assume that the CDMA

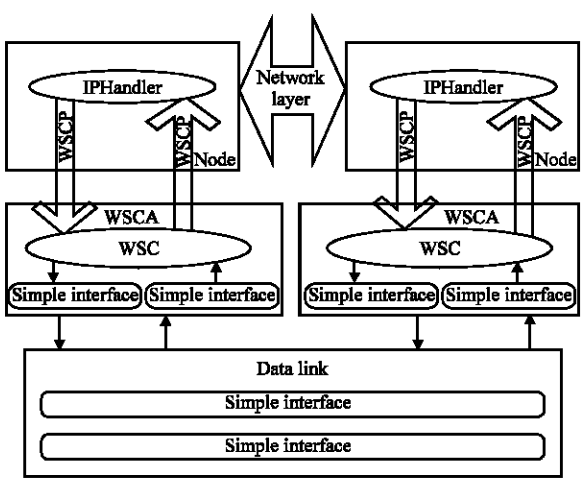

Fig. 2: Network layer and data link Layers for WSCP

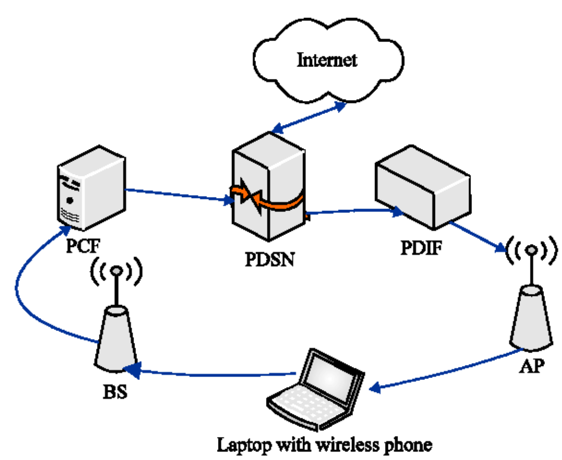

Fig. 3: CDMA-WLAN integrated network components

connection is already established under the overlapping area and the WLAN radio resource is available for setting up a new connection.

WSCP association: The WSCP association is initiated between the mobile node and the base station or the access point. Certain WSCP frame is used to initiate the WSCP association. The WSCP frame is based on the defined data frame types in 3GPP (2002). Within the MAC Header, the first two octets define 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. The format of the Frame Control field is shown in Fig. 4.

Within the Frame Control Field, there are Type and Subtype subfields. The Type field is 2 bits in length and the Subtype field is 4 bits in length. The Type and Subtype fields together identify the function of the frame. There are three frame types: control, data and management frames. Each of the frame types has several defined subtypes.

In the MAC header, as shown in Fig. 4 802.11 Frame Structure and Fig. 5 802.11 Frame Control Field, the following items are related specifically to our WSCP protocol:

- **Type/Subtype field:** Type/Subtype fields will be used to indicate that this frame is a WSCP 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, 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
- **Frame Check Sequence (FCS):** FCS will be computed over the entire aggregate header.

B0 B1	B2 B3	B4..B7	B8	B9	B10	B11	B12	B13	B14	B15
Protocol version	Type	Sybtype	To DS	From DS	More frag	Retry	Pwr Mgt	More data	WEP	Order

Fig. 4: 802.11 frame control field (3GPP, 2002)

B0	B1	B2	B3	B4	B5-15
ESS	IBSS	CF poll able	CF poll request		Reserved
Octets: 2					

Fig. 5: WLAN capability information field

0 1 2 3 4 5 6 7	8 9 0 1 2 3 4 5	6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1	
Command (1)	Version (1)	Routing domain (2)	
Address family identifier (2)		Route tag (2)	
IP address (4)			
Subnet mask (4)			20
Next nod (4)			
Metric (4)			

Fig. 6: Format of WSCP message

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

This frame is transmitted by the PDIF to AP in order to initiate association. 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 the WSCP.

WSCP frame format: The WSCP frame format is shown in Fig. 6. The following items are specific to our WSCP protocol:

- Command field defined message type and subtype of request or response. Type/Subtype fields explained earlier will be used to indicate that this frame is a WSCP frame
- Routing Domain field will be used to indicate that mobile nodes of one routing process can be located in both WLAN and CDMA2000 domains
- Next Nod field is set to IP address of the next node along the way. The necessary WSCP messages are generated from all nodes to all their neighbors. Therefore, this field is used to indicate the mobile node neighbor's IP address

The other frame fields are used to indicate the same functionality as explained in 3GPP (2002):

- Version is set to be 2
- Address Family Identifier for internet networks is always 2 for IP
- Route Tag provides support for EGPs
- Subnet Mask indicates the destination subnet mask (all 1's for host address) and
- Metric will be used to count node number of the special routing

Performance metrics: The WSCP is evaluated based upon throughput, whatever the wireless spectrum utilize efficiently or get higher data rates. Therefore, the throughput is the main metric for evaluating the WSCP performance. It is defined as follows:

Throughput: The CDMA 2000 network and WLAN are two different networks with different technologies and differing in bandwidth. The WLAN bandwidth is much wider than CDMA 2000 network. Regarding the bandwidth disparity, we establish the Mix-bandwidth data path for utilizing the two network resources to get higher throughput by implementing the WSCP. Thus, throughput can be used to evaluate the performance of this integration. 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 CDMA 2000 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) and occasionally in data packets per second. Relative to our research, throughput is defined as the total number of bits sent to the network 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.

RESULTS AND DISCUSSION

We have developed a simulation environment to evaluate proposed architecture. Simulation parameters for present simulation model are based on the values that accurately modeled the architecture proposed by 3GPP2. These simulation parameters are shown in Table 1.

PDIF functionality: 3GPP2 has specified the functionalities of Packet Data Interworking Function (PDIF) (Cerqueira *et al*., 2007). These functionalities have been presented earlier in this study. This value specified whether the Packet Data Interworking Function is enabled for the WLAN-MAC.

AP functionality: WLAN access point is one normal component in its network which is used to assign user request and reply. This value specified whether the access point is enabled for the WLAN-MAC.

WLAN physical layer characteristics: The simulation is run with the WLAN physical layer characteristics set to Direct Sequence Spread Spectrum (DSSS). The value of this attribute determined the physical layer technology in use.

WLAN data rate: Following the IEEE 802.11b standards, we set WLAN data rate to 11 Mbps. This value specified the data rate that is used by the MAC for the transmission of the data frames via the physical layer.

CDMA2000 1x-EVDO: Qualcomm's proprietary HDR (High Data Rates) technology dedicates a 1x carrier for fast data use only. This is called 1xEV DO (Data Only). CDMA 2000 1xEV-DO is specified in 2001 by 3GPP2, which introduces a new air interface and supports high data rates service for downlink. It requires a separate 1.25 MHZ carrier for data only, but the speed can be up to 3.1 Mbps on the downlink. Data transmission on supplemental channel is supported. This value sets for

Table 1: WSCP simulation parameters

Simulation parameters	Descriptions	Values
PDIF functionality	This value specified whether the packet data interworking function is enabled for the WLAN MAC	Enabled
AP functionality	This value specified whether the access point is enabled for the WLAN-MAC	Enabled
WLAN physical Layer characteristics	The value of this attribute determined the physical layer technology in use.	Direct sequence
WLAN data rate	This value specified the data rate that is used by the MAC for the transmission of the data frames via the physical layer.	11 Mbps
CDMA2000 1x-EVDO cell state	This value indicated that all CDMA 2000 1x-EVDO uplink and downlink traffic is sent on data control channels (DCCH).	DCCH

the simulation parameter indicates that all CDMA 2000 1x-EVDO uplink and downlink traffic are sent on the data control channels (DCCH).

WSCP simulation scenario: In order to simulate the new protocol, we have proposed simulation scenario which is presented in Fig. 7.

The primary focus of the scenario is the two access network used simultaneously for the mobile node. When the mobile node comes into the WLAN overlapping region from the CDMA2000 coverage area, the MN request will go through the first connection (MN→PDSN →CN) and the resulting reply will come through the second connection (CN→PDIF→MN). The scenario simulated a mobile node running the WSCP 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.

System implementation and test

System implementation: Present system has implemented on Java Network Simulator (JNS). Our implementation consists of the classes as presented in Fig. 8.

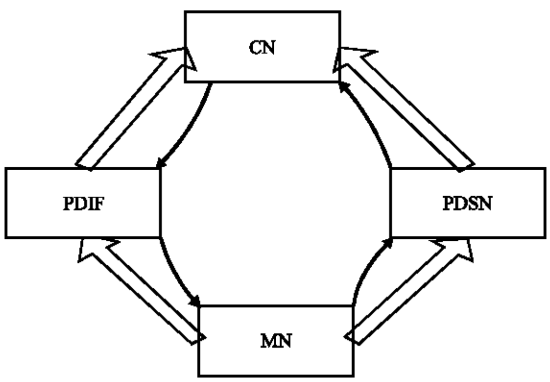

Fig. 7: Simulation scenario model

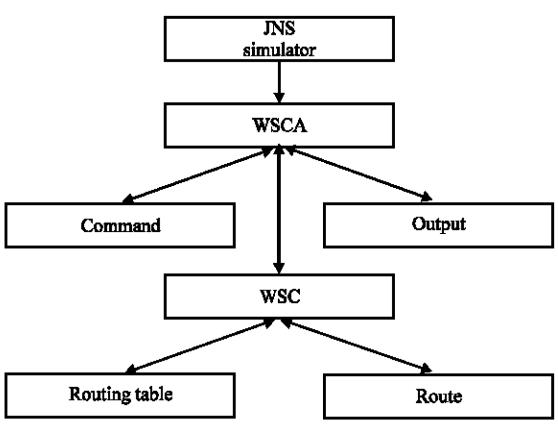

Fig. 8: WSCP class diagram illustration

The WSC class is core class which will be implemented in the essential algorithm associated with WSCP in our research. The WSC class is responsible for generating updates, sending them out, receiving updates and updating routing tables. Another important class is the class which holds all the information about the links in the network, which is the WSCA class. The other three classes are the classes to represent routes, routing tables and the update messages. These are respectively implemented in the Route, Routing Table and WSCP Message classes. The relationships between the Simulator class and the element package of JNS and the classes associated with WSCP are illustrated in the class diagram in Fig. 8.

System test: The designed WSCP protocol testing will be shown in this section. There are two items have been verified through out testing as follows:

- The simulation system test-this test is to verify that the WSCP protocol has been added into the simulation system
- The WSCP protocol testing – this test is to verify the WSCP functionalities

A bottom-up testing methodology has been adopted for the most part, 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 WSC class. When testing the updating of routing table, it could be seen that the rigorous testing involved up associated with the WSC class.

The WSC protocol testing results

Throughput and available bandwidth: 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 (Chen *et al*., 2007). 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.

Throughput is very important aspect that will determine the quality of service of wireless network for our WSCP protocol. During the WSCP simulation, if it works well on the integrated architecture, we get the relationship of the throughput and available bandwidth. We connect data of throughput and available bandwidth and then we generated the comparison for the throughput and available bandwidth which has been presented in Fig. 9.

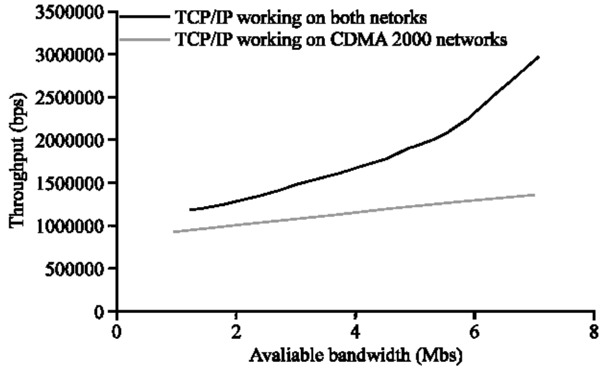

Fig. 9: Throughput vs available bandwidth

From the Fig. 9, it clearly shows the difference of throughput between data transmitted on the integrated architecture of CDMA 2000-WLAN and CDMA 2000 network data path. Once the WSCP is working on the different data paths, the two kinds of data paths can supply different throughput. The throughput in CDMA 2000 network data path is 384 Kbps with 1.25 M bandwidth channel. But in the integrated architecture, Fig. 9 shows that the throughput is much higher than the CDMA data path. Further more, the throughput is increasing when the available bandwidth increases under the integrated architecture of CDMA 2000-WLAN. Therefore, the proposed WSCP works on the integrated architecture can get higher data rates and utilize the two network resources.

CONCLUSIONS

In this study, we proposed a new protocol called Wireless Spectrum Combination (WSC) for combining two networks wireless spectrum in the convergence architecture. Data requests will be controlled by PCF (Packets Control Function) in CDMA 2000 network and data reply will be controlled by PDIF in WLAN network. Data traffic is routed through PDSN from CDMA 2000 network to WLAN network. The WSCP protocol has been defined to response for generating, sending out and receiving WSCP messages and subsequently using received updates to update the relevant routing tables. The simulation results have been evaluated through throughput parameters.

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

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