A Context-Aware Handoff Scheme and All-IP Mobile Multicast Service for Heterogeneous Wireless Networks

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Abstract*—With rapid development of wireless technologies, current user mobile devices can support to access various wireless networks such as Wi-Fi 802.11 Wireless LANs, 3G cellular networks, etc. Due to requirements of multicast mobility for multimedia services, the convergence of wired and wireless network has been a necessary trend in Next Generation Networks (NGN). The issues of multicast and mobility in the heterogeneous networks are very significant. Thus, the paper proposes an integrated framework for mobile nodes (MNs) and core networks to provide a seamless multicast mobility service according user contexts, i.e. user states and network states. The context-aware handoff process including the operations of system discovery, handoff decision, and handoff execution are designed for MNs. In addition, multicast agents (MAs) in the core networks are designed to deal with multicast connection management, which supports all IP multicast connection for multicast supported and non-multicast- supported networks. The prototype of the proposed framework has been implemented and tested. The performance measurements and system evaluation are shown, and the service disruption time during context-aware handoff can be minimized.

Keywords-context aware handoff; connection management; mobile multicast; heterogeneous network

I. INTRODUCTION

The widespread use of mobile terminals, currently equipped with multiple wireless network interfaces such as IEEE 802.11 WLAN (WiFi), Bluetooth (BT), and 3G (third-generation) cellular networks, can access Internet anytime and anywhere. Moreover, the convergence of wired and wireless technologies is identifying the requirements of Internet services especially for multimedia service provisioning, where mobile users are willing to have ubiquitous and continuous access.

In order to avoid the bandwidth waste of Internet streaming applications by data stream duplications and reduce the loading of central media servers, the IP multicast protocol is considered to employ for mobile multicast communications. However, seamless connectivity is a major challenge for handoff process in heterogeneous networks that deployed and operated by different Internet Service Providers (ISPs). In particular, the multicast connection maintenance is desirable for mobile users while they move between multicast supported and non-multicast-supported networks [1].

Most researches on handoff schemes [2]-[3] primarily address mechanism that relies on network information such as signal strength, bandwidth, etc. However, these handoff decision approaches depend on only the low-level network conditions and lack of considering the high-level application conditions, i.e. service quality, user intention and user contexts. Such inaccurate handoff decision may lead to longer delay time and lower throughput for the multimedia multicast service. Moreover, in heterogeneous networks, several wireless signals of Internet access services are existent simultaneously, and the service interruption of seamless handoff between each wireless networks would be more serious.

In this paper, we propose an integrated framework for mobile nodes and core networks to provide a seamless multicast mobility service according user contexts. The parameters of various available network status and host application service information are collected periodically. The context information is stored in the context awareness database to enforce the best strategy for horizontal handoff in homogeneous networks and for vertical handoff in heterogeneous networks, e.g. Wi-Fi, 3G cellular networks. The best one of available access points is selected based on user defined policies and network conditions. Finally, the user devices can receive the most suitable multicast connection and the best application service quality according to system environments.

The rest of this paper is organized as follows. Section II explores the important issues about handoff and related works. Section III describes our context aware handoff scheme and its implementation of integrated framework. Section IV presents multicast connection management. Section V demonstrates prototyping evaluations and performance experimental results of the proposed solution. Finally, we conclude the paper in section VI.

II. RELATED WORKS

There are three decision models for detecting the need for handoff in homogeneous and heterogeneous network conditions: mobile-controlled horizontal handoff (MHHO), network-control vertical handoff (NVHO), and context aware handoff (CAHO).

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A. *Mobile-controlled horizontal handoff*

The MHHO model is used in IEEE 802.11 WLAN networks, where the MNs continuously monitor the received signals strength (RSS) of the current attached AP. The horizontal handoff procedure is initiated once the measured value of RSSI is lower than the threshold [2]. To solve above problem caused by ping-pong effect, Pahlavan *et al.* [2] proposes the horizontal handoff decision algorithm to detect current RSS value compared with the old value by several complement parameters such as hysteresis margin, dwell timers and averaging windows.

B. *Network-control vertical handoff*

The NVHO decision model [3], [4] has been widely adopted by MN moving through WAAN (Wide Area Access Network), e.g. a wide coverage by low-bandwidth 3G Base Station (BS), to a wireless LAN, e.g. a small coverage by high bandwidth 802.11g Wi-Fi AP. Park *et al.* [3] and Hasswa *et al.* [4] proposes vertical handoff algorithm to monitor the network status by measuring the signals of surrounding APs and then determines the proper new network interface to switch, and the right time to take place of current network interface. However, such a vertical handoff decision method may cause some unnecessary and inefficient decision results, which will lead to network latency, low throughput, and even excess power consumption of the MN.

C. *Context aware handoff*

The CAHO decision-making model is based on the context information in terms of network, application service and users' preferences [5-7]. MN should be aware of all the possibilities offered by rule-based context-sensitive engine that infer user intention based on the information from their respective contexts. On the other hand, the smart handoff decision model [8-10] making by MNs provides intelligent context aware vertical handoff to achieve fast multicast connection switching and seamless multimedia services once moving to the most suitable wireless network. Paolo *et al.* [11] proposes the context servers for mobile users to move in a smart space with context information base. However, most researches do not access the impact of multimedia service to mobile multicast users.

With integrated all-IP mobile multicast service, our proposed framework can enhance the context-aware handoff functionality and utilize multicast agent to improve performance of handoff latency and throughput to increase the quality levels of user satisfaction.

III. PROPOSED FRAMEWORK AND IMPLEMENTATION

In this section, we propose an integrated framework by handoff and multicast connection management based on context information in Wi-Fi and 3G wireless access networks.

A. *Network Environment and Assumptions*

We assume that the 802.11 AP (Access Point) in WLAN (i.e. Wi-Fi) and 3G BS (Base Station) in WWAN (i.e. cellular network) are integrated in hybrid network environment as

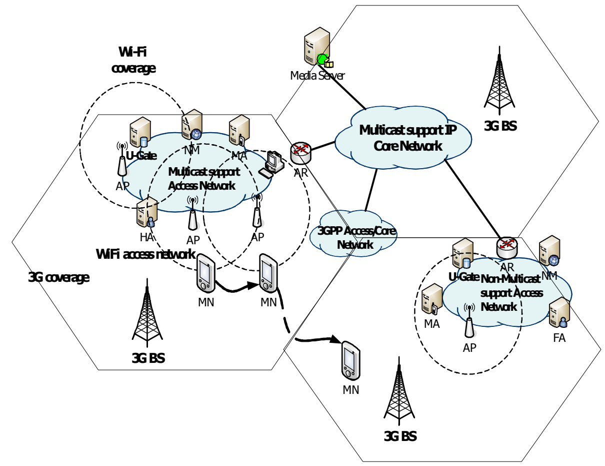


Fig. 1. Hybrid wired/wireless network environment

shown in Fig. 1. The mobile nodes (MNs), equipped the two network interfaces, are roaming and accessing to the Internet via one of two wireless access networks. The MN can select the proper one interface to access to the Internet for multicast multimedia service while moving between heterogeneous wireless networks. In IP multicast supporting core network, the access router (AR) is used as a multicast DR (designated router) to relay multicast packets to MN via wireless access network. With GGSN/SGSN gateway connecting to IP network in 3GPP core network, 3G wireless access network is extended to support IP multicast for MN. To collect network context information, the information database so called U-Gate (Ubiquitous Gateway) is used for the network context information exchange and update. To support all-IP multicast service, the multicast agent (MA) is established in each subnet to provide tunnel technology for MN's connection request for multicast data transmission to obtain multimedia services in non-IP multicast supporting access network. The MN will query the MA for seamless handoff mobility service.

B. *Context-Aware Handoff Process*

The context aware handoff scheme consists of three processes such as system discovery, handoff decision, and handoff execution. One of the main issues for seamless handoff across the heterogeneous wireless access networks is the timing of activation to take the handoff. The other issue is to make an accurate handoff decision and execute network switching effectively. The followings will explain the details for context information management and handoff decision-making process.

1) System discovery stage: Context aware handoff need to constantly monitor the context parameters for network state to assist the accurate handoff decision. Many of those parameters which are collected by system discovery are dependent on the adopted network interface card from MN, such as signal RSSI, ESSID, MAC, Bit Rates etc. In additions, Network Monitoring system (NM) adopts SNMP to extract more relevant network information from all AP and AR in each subnet such as multicast connections, data transmission rate, data receiving rate, network loading, and etc.

2) Context aware handoff decision stage: At first, the context aware handoff scheme will be triggered in either horizontal handoff or vertical handoff by detecting RSSI variation of APs to determine the mobile speed of MN in current network. Then, based on two factors of dwelling time in AP and estimating the priority of available APs, the handoff decision will be activate to choose the proper AP to connect. Finally, proposed scheme can reduce the frequent network switching due to unnecessary handoff.

Before performing handoff decision, it is important to verify the context information of current network environment. By detecting surrounding network conditions of MN in current network, the handoff decision function of MN is triggered by events to handle handoff decision as represented in Fig. 2. According to the pseudo code for handoff event trigger algorithm, the mobility speed is considered an imperative effect on handoff decision activation. When MN is moving through overlay coverage area of Wi-Fi and 3G network, we use MN moving speed as the primary handoff event trigger factor. The MN mobile speed can be estimated by the parameter of Average_variation_RSSI defined by the following equation:

$$Average\_variation\_RSSI = \frac{\sum_{i=1}^{N-1} | RSSI_{i+1} - RSSI_i | / RSSI_i}{N} \quad (1)$$

In Eq. (1), $RSSI_i$ denotes the RSSI of the *i-th* AP and N denotes the total number of the surrounding APs. While MN is moving at high speed across the heterogeneous network, the value detecting from (1) will be larger than the threshold to start the handoff decision. To reduce the ping-pong effect by frequent handoff event triggering, the threshold is set to count the number limit of temporary low RSSI of AP.

The proposed context aware handoff decision algorithm is determined by two factors: the dwelling time for existing service continuity and priority score for candidate APs with good signal quality RSSI in access network for multicast service. The dwelling time threshold can be defined via the formula:

$$T_E = \beta[\sum_{i=1}^{n-1} T_i /(n-1)] + (1-\beta)\, T_n \quad (2)$$

where T_E and T_n denote the threshold of dwelling time and the time the MN stays at *n-th* subnet, respectively. The term β is a constant weighting value, $0 \leqq \beta \leqq 1$.

The priority score function Q, which provides a measure of the context information of a certain network state. In order to adapt for different conditions, there is assigned weight for each parameter to calculate total quality value for handoff decision. The priority score function is defined by following equation.

$$Q_i = \sum_{i=1}^{n-1} \omega_t T_i \quad (3)$$

In (3), the w_t is denoted weight for each network parameters T_i. The weight values are fractions with the range from [0, 1].

The proposed context aware handoff decision algorithm applies the following major steps as represented in Fig. 3.

Step 1: The handoff decision is initiated by event handler based on RSSI and its variations.

Step 2: Predict the dwelling time in next possible AP according to previous AP dwelling time in link historic DB. If the estimated dwelling time T_E of the Eq. (2) is less than threshold value, MN will decide to handoff from Wi-Fi to 3G network

Step 3: While moving speed of MN is in low mobility, MN will scan the nearby available APs and filter the AP with RSSI below the threshold. Because the low RSSI of AP affects the wireless transmission quality, MN is usually to decide to start the handoff or remain to stay in 3G network.

Step 4: Choose the available candidate APs, and get their context information from U-Gate (or MA for horizontal handoff).

Step 5: Calculate the priority score of each candidate AP based on the different quality by Eq. (3). The highest priority is considered the same subnet with current AP, the second is the same multicast service for MN, and the third is multicast protocol support for router. At the same time the AP will be filtered because the signal strength of AP becomes weak less than threshold.

Step 6: After the priority sorting for candidate APs, the highest priority of the Wi-Fi AP will be selected as the target network to switch.

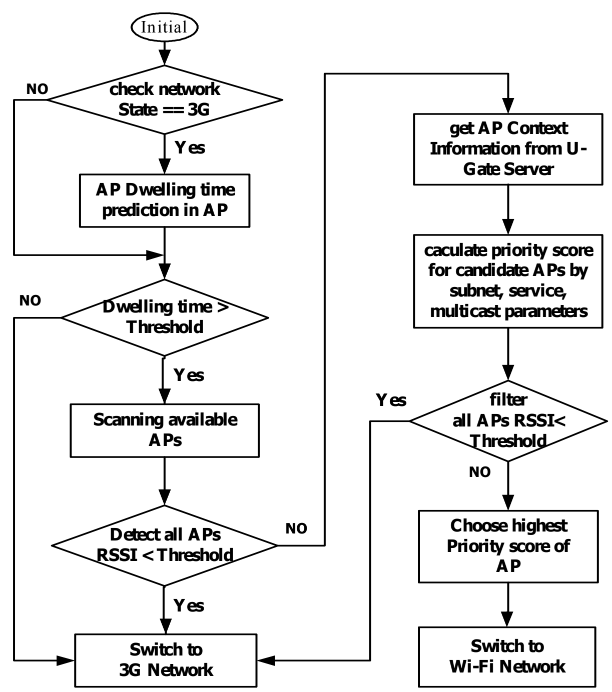


Fig. 3. Context aware vertical handoff decision procedure

3) Network Interface Switching: After handoff decision is determined, the process for changing the connection service mode is to execute network interface switching to another new AP or another new network. Both the connection service maintenance and network interface status changing (i.e. ON/OFF) are considered to achieve the seamless handoff connection. The pre-handoff request is used to inform MA to provide new multicast connection for MN mobility to obtain continuous multimedia services in heterogeneous access network. The multicast connection management will be explained in next section.

C. Implementation of Context-aware Handoff framework

In this section, the function modules for context-aware handoff framework and their corresponding context databases are implemented in software block diagram as shown in Fig. 4.

1) Context-awareness Database: The context information for mobile node can be monitored by its own network interface for local network status or acquired by the dedicated network management system like SNMP to poll network elements in widespread network environment. The context information stored in so called context-awareness database includes the following available parameters: Policy_DB: RSSI threshold, Counter, Dwelling time; Link_history_DB: MN connection number, MN dwelling time in AP; L2_AP_DB: ESSID, IP address, MAC address, data rate; Multicast_DB: group address.

2) Mobility Manager: The mobility manager supports mobile multicast service to provide context aware handoff process. Mobility manager processes handoff decision algorithm (see Fig.2) based on current context information. The function module consists of three entities: Event Handler to deal with the event to trigger handoff decision occurred, Handoff Decision to make handoff decision, Handoff Process to execute the network switching and handoff connection maintaining.

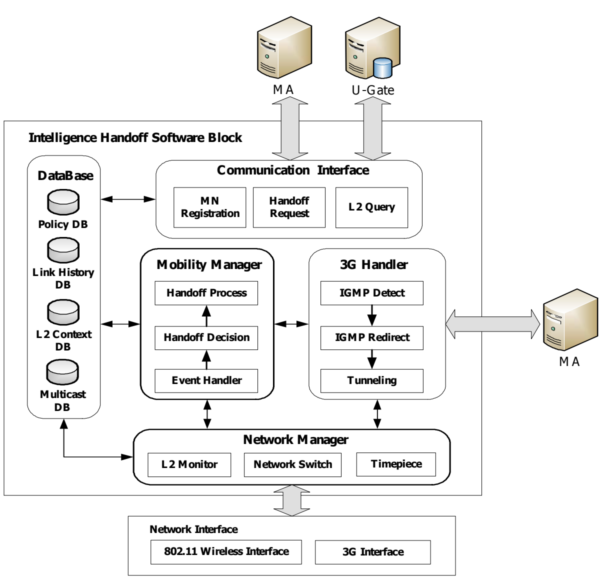


Fig. 4. The software blocks of context-aware handoff framework

3) Connection Manager: The connection manager provides the communication interface to register for MN, exchange control / management information for context database and the 3G multicast service handling for vertical handoff. The Communication interface function is used to exchange context information and send handoff connection request. One of the main function entities is to send the Handoff Request message by tunnel to remote MA for establishment of multicast connection in advance. The L2 (Layer 2) query function can acquire desired contexts from MA, including the available information such as AP status, multicast connection services. The 3G multicast service handler function detects and redirects the IGMP control message via tunnel through 3G core network to MA for multicast connection service when MN is moving from Wi-Fi to 3G networks.

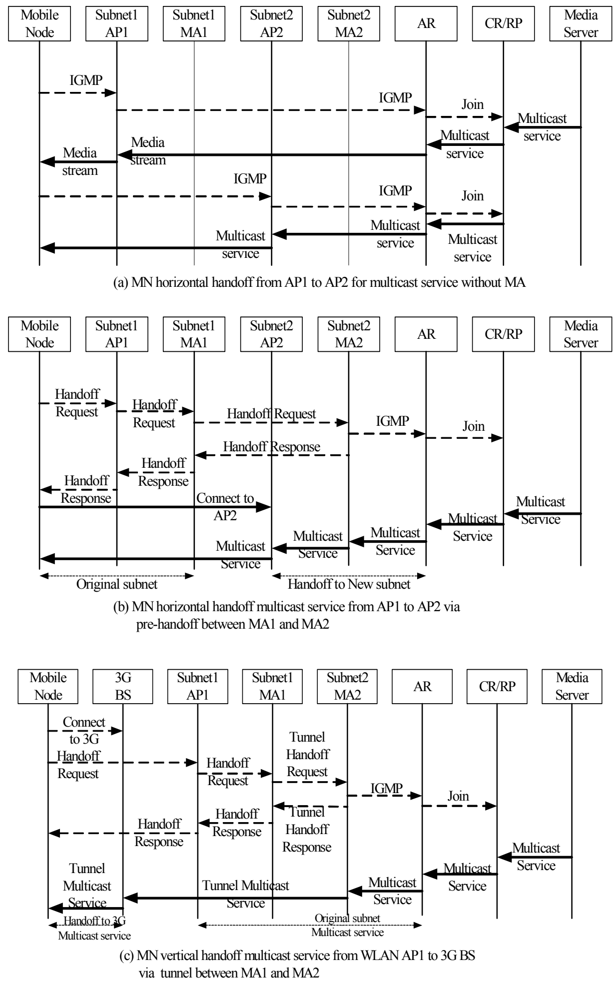
4) Network Manager: The Network Manager is to control different network interface switching between enable and disable state after handoff decision. The L2 Monitor function is used to detect current Wi-Fi RSSI quality, the connection availability in AP and the variation of RSSI. After handoff decision and connection is determined, the Network Manager will execute handoff decision to switch the specific network interface to connect the selected target device. At the same time, the timer Timepiece is refreshed to measure the staying time for each MN dwelling in the associated network device and stored as a context.

IV. MOBILE MULTICAST CONNECTION MANAGEMENT

In this section, we present our multicast agent (MA), the multicast connection manager, which can realize the All-IP mobile multicast connection service for heterogeneous networks such as Wi-Fi and 3G wireless radio access networks. While MN is moving to Wi-Fi or 3G access subnetwork, the MA will provide available multicast connection for MN to maintain seamless connectivity. Each MA is responsible for MN to request handoff multicast connection and provide multicast tunnel service for non-multicast supporting subnet.

The control messages for multicast service between media server and MN are illustrated as shown in Fig. 5. The RP (Rendezvous Point), CR (Core Router) and AR (Access Router) are multicast supported in backbone network. The AP (Access Point) and MA (Multicast Agent) are relaying multicast service in subnet access network. To take the advantage of MA, the pre-handoff request is to identify the new multicast connection by redirecting IGMP to achieve the multicast service via tunnel. In this example scenario of handoff, the steps for MN in both horizontal handoff and vertical handoff operations are explained as follows.

In Fig. 5 (a), we assume that MN initially visits AP1 in subnet1, and firstly sends the IGMP control message to local AR. When AR join the multicast group member, the multicast service can be achieved from media server through RP/CR based multicast tree to AR in subnet1. Then, the MN moves to AP2 in subnet2, the connection will be broken by handoff before the completion of rejoining.



(a) MN horizontal handoff from AP1 to AP2 for multicast service without MA

(b) MN horizontal handoff multicast service from AP1 to AP2 via pre-handoff between MA1 and MA2

(c) MN vertical handoff multicast service from WLAN AP1 to 3G BS via tunnel between MA1 and MA2

Fig. 5. Handoff sceneries of mobile multicast connection management

In Fig. 5 (b), considering the scenario of MN mobility with horizontal handoff, we take the feature of MA as the example to explain the multicast service continuation. The MN makes context-aware horizontal handoff decide to choose next AP2 while moving to neighboring subnet2. The MN first query the local multicast agent (i.e. MA1) in subnet1. Once after connecting to MA1, the MN sends the handoff request to MA2 through the tunnel between MA1 and MA2. After handoff responding, the MA2 sends IGMP message to AR to join the same multicast group. When MN roams to associate AP2, it will receive the multicast service from media server without breaking the connection.

In Fig. 5 (c), the vertical handoff scenario is considered for MN moving through Wi-Fi and 3G network. When MN is moving away from AP1 within 3G cellular coverage, the handoff control message will deliver through the tunnel between MA1 and MA2 to discover the multicast service. After the group member joining, the remote MA2 will relay the multicast service from AR to MN via tunnel through 3G access network.

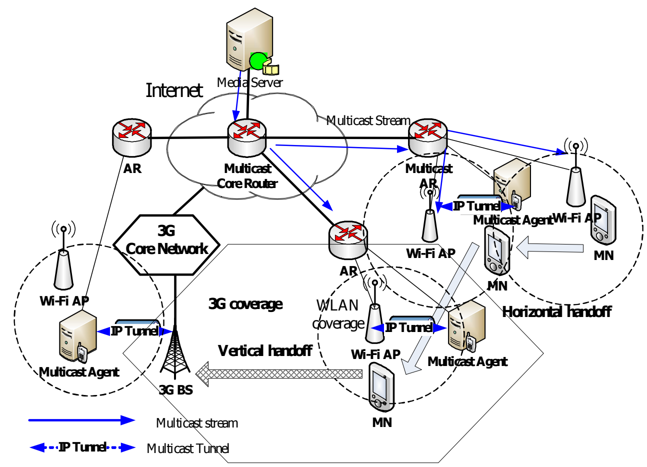


Fig. 6. The handoff scenarios for mobile multicast experiment

V. EXPERIMENTAL RESULTS

The proposed context-aware handoff software framework is implemented on pocket PC runs on Linux platform, which has Wi-Fi and 3G wireless interfaces as the prototype of mobile node. The performance evaluation is focused on the MN mobility with context-aware handoff feature between heterogeneous 802.11Wi-Fi network and 3G cellular network. The mobile multicast experimental network topology is setup as shown in Fig. 6. A multicast experimental network environment is constructed by one core router (CR) and three access routers (AR), which is supported by PIM-SM and IGMPv2. The media server connected to CR can generate uniform multicast media stream by the iperf software [12]. Our prototype MN sends the IGMP message to AR to join as the multicast group member and receive the multicast stream from visiting AP in current access subnet. Initially, the MN is connected to the Wi-Fi AP through multicast AR and CR for multicast service. The proposed multicast agent (MA) is employed to facilitate all-IP multicast service of handoff and tunnel for roaming MN in each subnet.

In test scenarios, we first observe the impacts of horizontal handoff between multicast supported Wi-Fi subnets. Secondly, , we evaluate the throughput of handoff by proposed context-aware handoff and MA to join the multicast tree. Finally, we measure the vertical handoff performance for MN's mobility from Wi-Fi network to 3G network. The MN activates the context-aware handoff decision making scheme while switching network interface between heterogeneous networks. The MA is requested to send IGMP message to join multicast tree and relay the multicast packets via tunnel to MN. The test results and performance analysis are discussed as follows.

A. *Handoff delay with passive and active IGMP*

We evaluate the performance of 802.11 inter-subnet handoff latency to affect multicast stream delivery. The IGMP control message in different version, which has passive and active mode, is used by MN to join multicast group in different modes. We measure and compare the handoff delay time between two multicast APs in different Wi-Fi subnets. Fig. 7

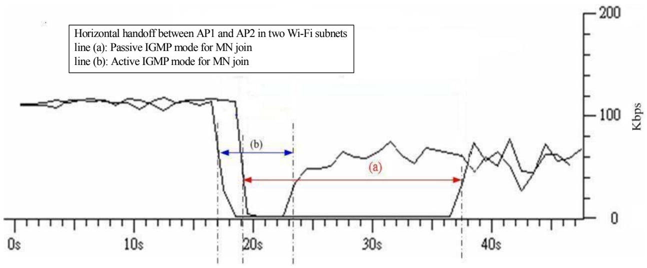


Fig. 7. Handoff delay time for multicast service: (a) passive IGMP join mode; (b) active IGMP join mode.

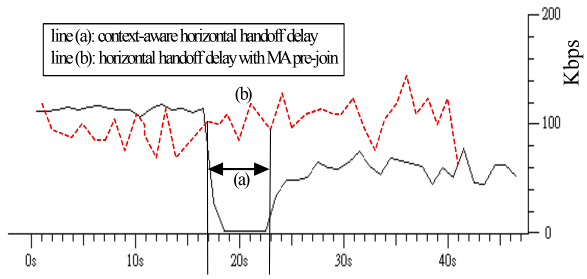


Fig. 8. Multicast seamless service horizontal handoff with MA pre-join

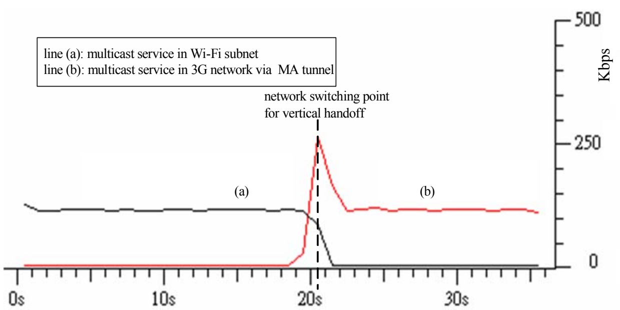


Fig. 9. Vertical handoff test for seamless multicast service from Wi-Fi to 3G networks

shows the results with *x*-axis indicating the handoff delay time measurement and the *y*-axis indicating the receiving multicast data stream rate. It shows that horizontal handoff across different subnet with passive IGMP join for multicast service may occur longer delay time about 14 sec within the time interval of line (a). There is a minor improvement to shorten the delay time to 6 sec within the time interval of line (b) as the active IGMP join request in new multicast subnet.

B. Throughput and delay with context-aware horizontal handoff

In this experiment our goal is to show that, by deploying MA, the MN is to use handoff request to desired MA in neighboring subnet to send IGMP for multicast services i.e. re-joining the multicast service or register to home agent to relay the multicast data through the tunnel. With the context aware handoff and MA functionality in each subnet, the multicast services can avoid disruption or disconnection of the active connection for MNs. In addition to proposed context-aware handoff scheme, the MA in next subnet can maintain high quality of multicast connection from AR soon after MN moving to the new subnet. Fig. 8 demonstrates that the results of our proposed scheme (i.e. line b) is more efficient than traditional handoff (i.e. line a) in throughput and handoff delay in heterogeneous network.

C. Vertical handoff delay test with MA tunnel

In vertical handoff test scenario, when MN monitors the weak RSSI in current AP, MN will estimate the mobility factor to trigger handoff event. Since we assume there is no multicast supporting in 3G networks, the MN will get IP address for 3G interface to send IGMP message via IP tunnel. The MA is employed for MN to deliver multicast stream to MN in 3G cellular networks. During the network switching point from 19 sec to 22 sec time period, the flow rate of multicast stream will increase to be twice amount because the original Wi-Fi network and current 3G network are overlaid within the handoff region, as shown in Fig.9. When the 3G multicast streams arriving at a steady state, the Wi-Fi network interface will be disable to transmit multicast data flow. Therefore, the proposed vertical handoff scheme can achieve seamless multicast connection.

VI. CONCLUSIONS

In this paper, we have presented a context-aware handoff process and multicast agent in heterogeneous networks for all-IP mobile multicast service. One of the main contributions in this work is to propose an integrated framework for mobile node which is implemented by the four function modules: mobility manager, connection manager and network manager associated with the context database for mobility aware multicast application and connection operations. Another one is the multicast connection management to be performed efficiently by multicast agent in Wi-Fi and 3G heterogeneous networks. Therefore, the mobile nodes can make the accurate handoff decision to activate the proper network interface switching to achieve the seamless multicast connection. That can avoid the discontinuity of current multimedia application services and provide the fast multicast connection during handoff process. The prototyping system evaluation and performance analysis indicate that our proposed framework performs the best quality as expected in context aware handoff and multicast connection management. Nevertheless, in future there leaves more improvement spaces in development of our framework on the fields of multicast QoS and resource allocation in mobile multicast network.

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