A Novel Mobile Multicast Video Streaming System over IEEE 802.11 Wireless Mesh Networks

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Abstract- *This paper proposes a novel multicast real-time video streaming system with seamless handoff scheme over IEEE 802.11 wireless mesh networks (WMNs). In a WMN, the mobile station (MS) may change its association from one access point (AP) to another owing to poor link quality. However, the video stream could be disrupted or discontinued after handoff because that the handoff scheme does not choose the appropriate access point. Many handoff schemes have been proposed in order to decrease handoff time or latency. Most of them, however, do not consider the problem of maintaining the quality and continuity for the ongoing multimedia streaming services. In this paper, therefore, a novel handoff scheme is proposed to achieve seamless playback of ongoing video streams during handoff. As a result, MSs can move anywhere in the mesh network without receiving discontinuous video streams.*

Keywords: wireless mesh networks, handoff, multimedia streaming services

1. Introduction

In recent years, people are interested in wireless local-area networks and widely deploy them in many places like campuses, companies, shopping malls, hotels, etc. Furthermore, due to the fast development on RF technologies and the wireless MAC protocols, wireless mesh network (WMNs), in which all access points connecting each other via wireless RF links, has become the trend of next-generation structure of wireless access networks. WMN has 2-tier architecture consisting of several mesh nodes (MNs) and mobile stations (MSs), shown as Figure 1. The first-tier network (or called as *tier-1 network*), which is formed by all the mesh nodes, is used to transfer data between the mesh modes. Some of the mesh nodes may also act as the access points for MSs. Such MN is called MAP. The network formed by each MAP as well as its associated MSs is the second-tier network (or called as *tier-2 network*). The RF channels used in both tiers are certainly different. Unlike the Ad Hoc network, there is surely at least one MN connected to the wired network in a mesh network due to its role as an access network.

Video stream technologies have been widely applied in entertainment, home care, video conference, remote teaching, etc. Especially, broadcast and multicast IPTV service are strongly promoted currently [1]. Since IPTV is operated on Internet in which heterogeneous networks are inter-connected, each type of network, including WMNs, should provide QoS maintenance mechanisms to guarantee the desired playback quality.

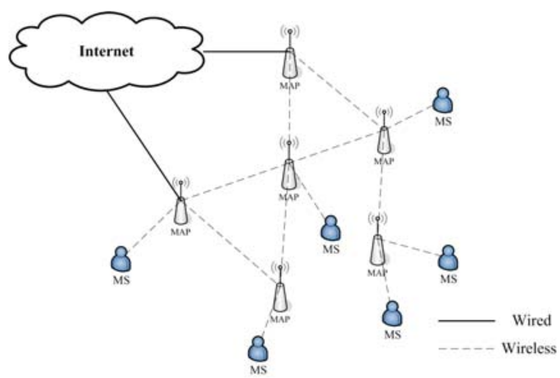

Figure 1: Mesh network architecture.

The research in this paper concentrates on the design of multicast streaming system and the related handoff problem on IEEE 802.11 WMNs. A novel multicast real-time video streaming system with seamless handoff scheme is proposed. The considered handoff problem is to resolve the discontinuity of video streams on an MS caused by associating from the original MAP to the new one. An MS could loss data during the handoff process. Certainly, it will have broken video streams with missing episodes. There have been several handoff schemes on WMNs or wireless ad hoc networks proposed by many researchers. Most of them are interested in decreasing the handoff time, the handoff latency and the framework [4][5][6].

However, these schemes are unable to solve the broken video problem. The goal of the proposed solution in this paper is to achieve continuous playback of video stream when the MSs perform handoff.

In the proposed multicast video streaming system on IEEE 802.11 WMN and the resolution of handoff problem, the investigated video stream coding scheme is Scalable Video Coding (SVC) [2]. SVC is the trend on video coding for modern video transmission system. Among several kinds of SVC, Fine Granularity Scalability (FGS) is a MPEG-4 coding tool that allows for the creation of flexible and scalable video bit streams that deliver higher compression efficiency. FGS encodes the video into base layer (BL) stream and enhancement layer (EL) stream. The BL stream can be decoded alone to show a video with the poorer quality while the EL stream is only used to combine with the BL to enhance the quality. In the proposed solution for handoff problem the above characteristics of FGS is considered to realize continuous playback of video stream.

The rest of this paper is organized as follows. Section II presents the required related work. The detailed explanation of proposed multicast video streaming system on IEEE 802.11 WMNs is provided in Section III. The solution of handoff problem is illustrated in Section IV. Finally, the future works and the conclusions are discussed scribed in Section V.

2. Related Researches

The major issues in multicast video streaming system are the routing path of its multicast traffic. There were many researches focus on the mechanism of building an efficient routing path in multicast network system. Multicast Optimized Link State Routing (MOLSR) is a well-known example [3]. There are two structures to transmit multicast traffic, tree-based and mesh-based. Trees are built per group with a core and mesh structure are built for each multicast group. Figure 2 illustrates an example of tree-based multicast architecture in a WMN. There is a multicast tree built in tier-1 network and some MSs, which are the member of the multicast group, are registered in tier-2 network under this tree in the mesh network. Tier-1 network is responsible of the communications between MAPs/MPs. The multicast data are transmitted from MAP to MS using multicast MAC frames in tier-2 network. For example, MAP3 is the root of the multicast tree in tier-1 network. MAP3 multicasts the data to both MAP7 and MAP9, and then MAP7 multicasts data to both MAP11 and MAP13. The MAPs then multicast data to their associated MSs, respectively.

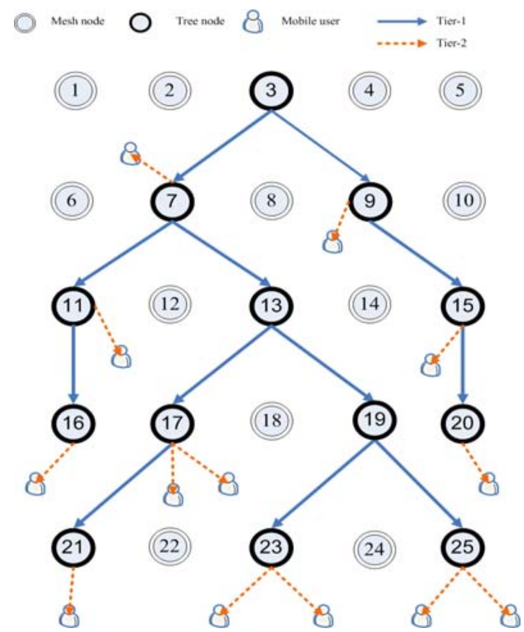

Figure 2: An example of tree-based multicast structure in WMN.

Handoff occurs whenever a mobile station needs to change its association from one AP to another. Handoff processes includes two parts including deciding handoff time and re-authentication to new AP. There are many handoff schemes on ad-hoc or wireless network that have been proposed. Most of these schemes discussed about handoff latency decreasing and framework for handoff [4][5][6]. However, they did not concern the continuity playback for multimedia streams. It is possible that the playback will be broken during the handoff process. The common mechanism for deciding when handoff should occur is to initial handoff whenever the current AP's *Received Signal Strength* (*RSS*) drops below a threshold and select the one with strongest RSS as the new AP. However, using RSS alone to decide new AP might force the user to hold on the undesired AP. There is a continuity of video stream handoff scheme on Mobile IP called SMM [7], it adopted an extra handoff buffer to achieve seamless handoff.

3. Multicast Video Streaming System on WMN

In this session, we describe the proposed multicast video streaming system architecture. WMN is composed of several MAPs/MPs and

MSs. Some of these MAPs/MPs must be the gateway connected to Internet by the backhaul network. Each MAP or MP transmits data to and receive data from its neighboring MAPs or MPs via wireless links. If the destination of the received data is at another MAP (or MP), the receiving MAP (or MP) will forward them to its neighbor according to specific routing algorithms. If the destination of the received data is the associated MSs of the receiving MAP, the data will be forwarded to the destination MSs via the wireless link in the WLAN managed by the MAP.

In the proposed system, it is assumed that the sources of the video streams are located in the backhaul network or located at the gateway MAPs or MPs of WMN. In order to multicasting the video stream to the subscriber MSs in the WMN, a multicast tree with the gateway MAP (or MP) as its root should be constructed in tier-1 network of the WMN. The multicast tree may be constructed by some specific multicast routing algorithm, e.g. MOLSR discussed in Section II. Let '*subscriber MAP*' denote the MAP with which at least one subscriber MS of the video stream associates. The data packets of the video stream are forwarded from source MAP (or MP) to the subscriber MAPs along the multicast tree. As the video stream data arrive at the subscriber MAP, it will be buffered in the MAP and then multicasted or broadcasted in the MAP's tier-2 network via IEEE 802.11 MAC protocol. Each subscriber MS receives and buffers the multicasted or broadcasted packets for playback.

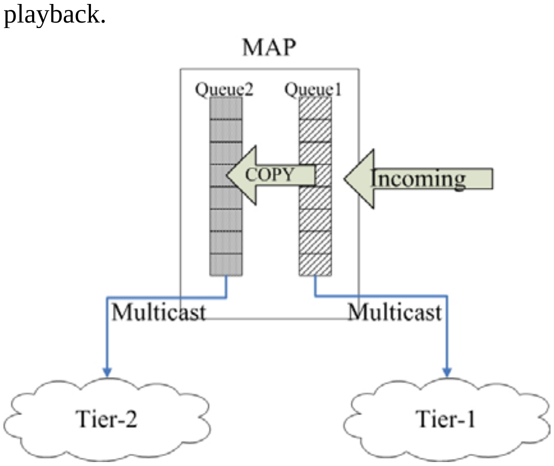

Figure 3: Conceptual structure of buffering mechanism in subscriber MAP.

To reduce the delay jitter caused in tier-1 network and simplify the jitter buffer control on subscriber MSs, the subscriber MAP is required to buffer a continuous segment of the video stream with limited length and follow the QoS requirement when multicasting or broadcasting the video stream data. The conceptual structure of the above buffering mechanism is shown as Figure 3. The incoming video stream packets are buffered in Queue1 for later forwarding to next-hop neighbors In addition, these packets are copied to Queue2 simultaneously for later multicasting or broadcasting to subscriber MSs in tier-2 network.

Further, MS may not be able to receive packets during handoff process. This will cause discontinuity video playback. For this problem, the proposed solution is to require MS to buffer the video segment that is possibly lost for playback in the handoff duration. It will be described later in Section 4.

In addition, there also exists synchronization problem in playback timing among subscriber MAPs. This problem is caused by the packet forwarding in tier-1 network and the proposed buffering mechanism for smooth playback. In tier-1 network, packets are transmitted by complying with IEEE 802.11 MAC protocol, i.e. DCF or EDCA. In DCF, the station which has data to transmit must sense the wireless channel. If the channel is idle, it must wait for a duration of DIFS (Distributed Inter-Frame Space) and random backoff time before transmission. EDCA, which is proposed in IEEE 802.11e, is the enhancement of DCF in QoS. EDCA provides several mechanisms on QoS in which the data may be transmitted according to its QoS requirement. No matter what 802.11 MAC protocol is used, the data should be buffered before been forwarded to the next-hop MPs and the length of routing path between two MPs is different. Thus, the end-to-end delay of one pair of MPs is different from the delay of other pairs. Such difference of end-to-end delay may cause the playback timing of one subscriber MAP different from another's. Furthermore, in the proposed buffering mechanism, each subscriber MAP may tune its buffer (i.e. Queue2 in Figure 3) length according the wireless link condition of its tier-2 network. This may also cause difference of playback timing among MAPs. Such difference in playback timing will lead to discontinuous video stream after handoff. Figure 4 illustrate an example of this problem. The playback time of the video stream in MAP1 is at 3"15 while the playback time in MAP2 is at 3"20. Once the MS handoffs from MAP1 to MAP2, it will lose the video data between 3"15 and 3"20. Thus, the continuity of video stream in MS is broken.

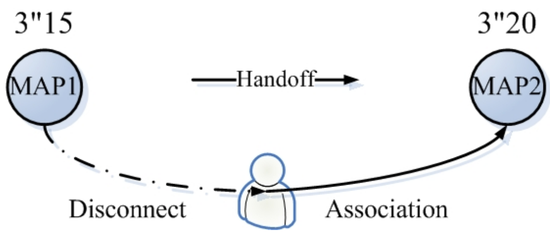

Figure 4: non-synchronize video stream

In this paper, Fine Granularity Scalability (FGS) approach in MPEG-4 stander is considered as the encoder scheme of the video stream. It encodes a raw video into basic layer (BL) stream and enhancement layer (EL) stream. The BL stream can be decoded alone to show a video with poorer quality while the EL stream is only used to be combined with the BL stream to enhance the quality. In general, the data rate of BL stream is lower than the one of EL stream. In the ongoing simulation of the proposed system, it is assumed that the data rate of BL stream and EL stream rate is 256 Kbps and 768 Kbps, respectively. Note that in order to achieve continuous playback of a video stream for an MS after handoff to a new MAP, the new MAP needs an extra buffer (named as *handoff buffer*) to continuously cache a segment of the BL stream that has been transmit to the other MSs originally associated to this MAP. The contents in handoff buffer may be transmitted to the new arrival MS for maintaining the continuity of playback.

4. Proposed handoff mechanism

A. Handoff process

Figure 5 illustrates the process of handoff when an subscriber MS is associated to a new MAP in the proposed system. Note that the video is encoded by FGS scheme here. MAP must cache the BL stream that has been transmitted to the originally associated MSs in its handoff buffer. After starting handoff process being disassociated with the original MAP, the MS cannot receive the video stream data but still can continuously playback the complete video stream (BL stream plus EL stream) stored in its internal buffer. After being associated to the new MAP, the MS can request the new MAP to transmit the contents in the handoff buffer in bursty manner, such that the MS can still continuously play the video even if it exhausts the data in internal buffer. Note that the handoff buffer only caches BL stream data to save the bandwidth in wireless link and the buffer size of the MAP. Therefore, the continuous playback can be maintained but with poorer quality. However, the duration of poorer-quality playback is short since most handoff procedures will be finished in at most several seconds. After receiving the contents in handoff buffer of the new MAP, the MS has all the BL stream data whose duration is from the time of internal buffer exhaustion till the current playback time of the new MAP. Then, MS may receive the normal multicasted complete video stream (BL stream plus EL stream) from the new MAP and the playback quality is back to better.

In fact, the synchronization problem in playback timing among subscriber MAPs will influence the procedure of handoff decision and handoff process. All the possible cases are discussed as follows.

- *Case 1 – The new MAP is outside the multicast tree:* In this case, the MS is associated to a new MAP that is not in the original multicast tree. Therefore, the multicast tree must be modified to transmit video stream packets to the MS. The proposed method of modifying the multicast tree is to connect the new MAP to one of the MAPs in the original tree. We define the cost of connecting the new MAP to the original tree is C_{mt} and the handoff decision should minimize C_{mt}.

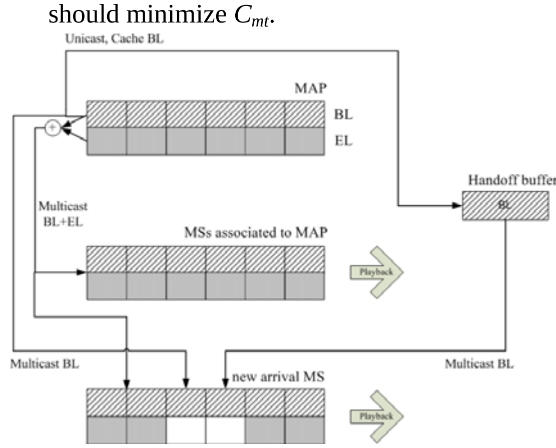

Figure 5: Handoff scheme

- *Case 2 – The new MAP is inside the multicast tree:* In this case, it is not necessary to modify the original multicast tree and thus extra bandwidth is not needed. Two different situations in this case are discussed as follows, respectively.
  - *Case 2-1: The new MAP's playback timing is ahead of the MS's:* The proposed scheme with extra handoff buffer for transmitting BL stream to the MS is adopted to continue the playback with poorer video quality.

- *Case 2-2: The new MAP's playback timing is behind the MS's:* Similar to the other cases, in order to achieve synchronized playback, the MS has to buffer a segment of video stream for playback in handoff duration. During the handoff process, the MS continuously plays the video stream stored in its internal buffer. Once the buffered video stream has been exhanusted, the playback in this MS will be broken since the timing of the normal multicast video stream in the new MAP is behind the MS's. As shown in Figure 6, The new arrival MS will play segment 10 to 12 after being associated to the new MAP. At the time when finishing the playback of the 3 segments, the MAP just transmit segment 11. The playback of new arrival MS will be broken since it cannot have the required segment 13.

To solve this problem, we propose a mechanism, named as '*Burst Push*', to pull up the playback timing of the MAP with the new arrival MS. It is illustrated in Figure 6. After the new arrival MS being associated to the new MAP, the MAP multicasts segment 8 to 12 in bursty manner instead of following the timing of the video stream. After the bursty transmission, the MAP multicast the following segments (from segment 13) with the original timing again. Thus, the playback timing in the new MAP is pulled up with the new arrival MS.

Burst Push mechanism can resolve the timing synchronization problem without extra required bandwidth. The tradeoff is that all the MSs except the new arrival one must enlarge the internal buffer to cache the bursty incoming video stream data. The internal buffer of MS may not be enlarged unlimitedly by controlling the MAP's multicast timing. Once the new arrival MS causing buffer enlargement moves to another MAP, the MAP which performs Burst Push may notify the MSs to reduce the buffer size and temporarily stop transmitting video stream data for compensating the buffer enlargement.

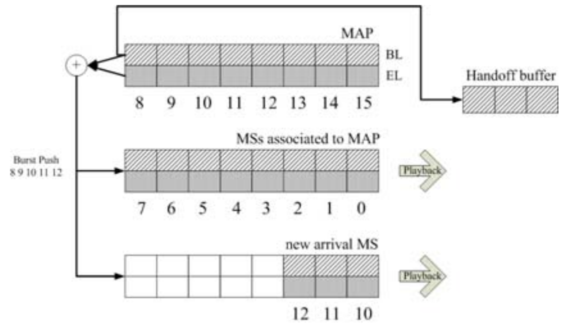

Figure 6: Burst Push

B. Handoff decision algorithm.

To avoid waste on the network resource, it is necessary to decide the most appropriate MAP when an MS needs handoff. To achieve this goal in the proposed system, the principles for choosing MAP is listed as follows:

1. Choose the MAP whose signal strength (i.e. the value of RSS is in reasonable range and is in the multicast tree.
2. Choose the MAP with which the interval of poorer video quality during handoff process is minimal.
3. Choose the MAP with which the enlargement of internal buffer for the MSs associated to the MAP is minimal.

The proposed handoff decision algorithm is presented as follows:

Handoff decision algorithm

```
Input:   MAP_i, RSS_i, MAP_VT_i, MS_VT, Threshold,
         VTD_min = ∞, Ca_i, for all i=1,…,N
Output:  The selected MAP
         Begin
         //Step 1: MS searches MAPs in the signal range
                 and records their RSS and playback time

         //Step 2: MS chooses the MAPs whose RSS_i >
                 Threshold as the candidate MAPs
             for (each MAP_i in the set of found MAPs){
               if (The RSS_i > Threshold)
                  Ca_i ← MAP_VT_i; }

         //Step 3: MS calculates the cost of modifying
                 multicast tree
             If ( all found MAPs in step 2are not in
             multicast tree){
                Calculate the hop count from each found
                MAP to the nearest MAP in the multicast
                tree;
                Choose the MAP with minimum hop count
                as the selected MAP; goto End; }

         //Step 4:select the MAP with smallest difference in
                playback time
             for ( Each MAP_i found in step 2 and located
             in multicast tree) {
               If (Ca_i!=0 && |Ca_i–MS_VT| <VTD_min) {
                  VTD_min ← |Ca_i–MS_VT|;
```

```
        Set the selected MAP as MAPi; }}
End.
```

There are seven input parameters in this algorithm listed as follows:

- MAP_i: the MAP in the WMN in which there are *N* MAPs.
- RSS_i: the value of RSS of MAP_i measured by the MS.
- MAP_VT_i:the current playback time of MAP_i.
- MS_VT: the current playback time of the MS.
- VTD_min: the minimal value of the difference in playback time between the selected MAP and the MS.
- Threshold: the threshold of RSSi for choosing candidate MAPs.
- Ca_i: the candidate MAP.

The steps in the algorithm are explained as follows:

Step 1 and Step 2: The MS searches the MAPs whose RSS values are large enough to allow handoff. The found MAPs are called candidate MAPs and their playback time are recorded in parameter Ca_i..

Step 3: If all candidate MAPs are not inside the multicast tree, the multicast tree must be expanded to include the selected MAP during the handoff process. The MAP with minimal cost of the expansion should be chosen. In this algorithm, the cost is defined as the minimal hop counts from the selected MAP to one of the MAP in the original multicast tree. The value of the cost is calculated for each candidate MAP and the one with minimum cost is selected as the new MAP for handoff.

Step 4: If some candidate MAPs are located in the multicast tree, the MAP for handoff are selected among these MAPs inside the multicast tree. It is not necessary to expand or modify the multicast tree. The criterion for choosing the desired MAP is to choose the one which has the minimal difference in playback time with the MS.

5. Conclusion

We presented in this paper a novel mobile multicast video streaming system over IEEE 802.11 wireless mesh networks. The main advantage of this system is that it ensures continuity of video stream playback at the mobile station during handoff process. Furthermore, with the proposed handoff mechanism, the mobile station selects the desired MAP that has minimal cost in the expansion of multicast tree and the minimal difference in video playback time to save the required bandwidth and buffer size. The ongoing work is implementing the simulation system using NS-2 [8] and evaluating its performance on bandwidth saving and playback quality.

References

[1] International Telecommunication Union, "IPTV Focus Group Proceeding," *ITU-T*, 2008.

[2] H. Schwarz, D. Marpe, and T. Wiegand, "Overview of the Scalable Video Coding Extension of the H.264/AVC Standard," *IEEE Transaction on Circutis and Systems for Video Technology*, VOL. 17, NO. 9, Sep. 2007.

[3] A. Laouiti, P. Jacquet, P. Minet, L. Viennot, T. Clausen, and C. Adjih, "Multicast optimized link state routing". *Technical report, INRIA Rocquencourt*, Feb. 2003. (ftp://ftp.inria.fr/INRIA/publication/publipdf/ [1]. RR/RR-4721.pdf.)

[4] O. S. Yang, S. G. Choi, J. K. Choi, J. S. Park, and H. J. Kim, "A Handover Frame work for Seamless Service Support between Wired and Wireless Networks," *ICACT*, vol 2., May, 2006.

[5] V. M. Chintala and Q.-A. Zeng, "Novel MAC Layer Handoff Schemes for IEEE 802.11 Wireless LANs," *Proceedings of IEEE WCNC*, pp. 4435-4440, March, 2007.

[6] K. Wu and J. Harms, "Performance Study of Proactive Flow Handoff for Mobile Ad Hoc Network," IEEE *Wireless Networks*, pp. 119-135, December, 2006.

[7] I.-C. Chang and K.-S. Huang, " Synchronized Multimedia Multicast on Mobile IP Networks," *Proceeding of IEEE ICC*, vol.2, pp. 799-803, May, 2003.

[8] http://www.isi.edu/nanam/ns.