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Distributed Medium Access Control for N-Screen Multicast Services in Home Networks

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ABSTRACT

N-screen is an emerging technology to support multimedia multicasting, content sharing and content mobility. N-screen service providers should obtain the technology that provides the highest quality content seamlessly. Distributed nature of WiMedia distributed-MAC protocol can provide full mobility support, and achieves seamless medium access method in contrast to IEEE 802.15.3. So, in this paper, WiMedia distributed-MAC protocol is adopted and an asynchronous multicast transmission (AMT) technology is proposed to enhance performance of seamless N-screen wireless service based on distributed-MAC. The ACK frame transmissions are not required for multicast transmissions. By using this property in AMT, if a device is a multicast receiver, its reserved time slots can be reserved by the other devices with 1-hop distance. Furthermore, each N-screen device broadcasts and shares the information including an order in asynchronous traffic reservations to reduce conflicts in determining the transmission order of asynchronous N-screen packets. Therefore, AMT scheme expands the number of time slots available and throughputs for multicast and asynchronous traffic reservations when comparing with the distributed-MAC standard system. N-screen communications based on distributed-MAC with the proposed AMT shows a new framework for realizing N-screen wireless service with the full content mobility.

Key words: Home Networks, Distributed MAC, N-screen, Multicast

1. INTRODUCTION

N-screen is an emerging technology and demand of future to support multimedia multicasting, content sharing, content mobility, media scalability, media synchronization, and seamless mobility. P2P streaming technology is mainly used as the technology that uses service network efficiently, and adaptive streaming technology is mainly used as the technology that ensures seamless video streaming. As shown in Fig. 1, P2P streaming is not the technology that receives service content from server, but the technology that receives service content from close client. P2P streaming technology has the disadvantage that it uses the resource of user's device and network, but it has the advantage that provides a better quality of service by reducing the server load and network costs. In addition, because the most P2P streaming technology measures user's resource in advance, users do not interfere with the use of their devices [1-2].

The WiMedia Alliance has specified a Distributed Medium Access Control (D-MAC) protocol based on UWB for High-Rate WPANs [3-4]. The WiMedia D-MAC supports a distributed MAC approach. In contrast to IEEE 802.15.3, D-MAC makes all devices have the same functionality, and networks are self-organized and provide devices with functions such as access to the medium,

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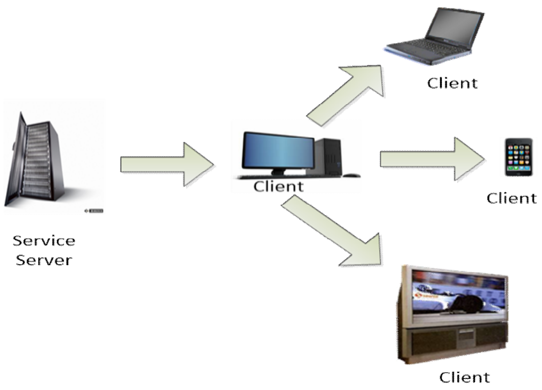

Fig. 1. P2P-based streaming for N-Screen Services.

channel allocation to devices, data transmission, quality of service, synchronization in a distributed manner. The WiMedia D-MAC removes the Simultaneous Operating Piconet (SOP) of 2-hop range packet collision problems of the centralized IEEE 802.15.3 MAC by adopting the distributed architecture. D-MAC employs beacons for distributed clock synchronization, and exchanges of channel reservation information and control packets among devices [3-4]. In D-MAC, each node broadcast its own beacon which contains Information Elements (IEs) per a periodic interval called a superframe. IEs convey certain control and management information. The distributed nature of D-MAC protocol can provide full mobility support, and achieves scalable, fault tolerant medium access method.

In this paper, a D-MAC protocol is adopted for development of a seamless N-screen wireless service. Furthermore, to provide the OSMU (One Source Multi Use) N-screen service through P2P streaming in the seamless D-MAC protocol, an asynchronous multicast transmission (AMT) technology is proposed in Section 2. And in Section 3, we designed the AMT in P2P N-screen services and simulated it for performance evaluation. In Section 4, conclusions for this paper are presented.

2. ASYNCHRONOUS MULTICAST TRANSMISSION (AMT) TECHNOLOGY

D-MAC operates per a time unit of a superframe. The superframe has a fixed length of time, and it is split into a plurality of time windows called a medium access slot (MAS). The superframe consists of 256 MASs. In Fig. 2, a superframe is divided into two parts: a beacon period (BP) followed by a data transfer period (DTP). Data frames are transmitted during the DTP. The MAC provides asynchronous and isochronous data communication services [3]. The isochronous service is supported by the Distributed Reservation Protocol (DRP), which allows bandwidth reservation to be handled in a fully distributed manner. The asynchronous service is provided by a prioritized carrier

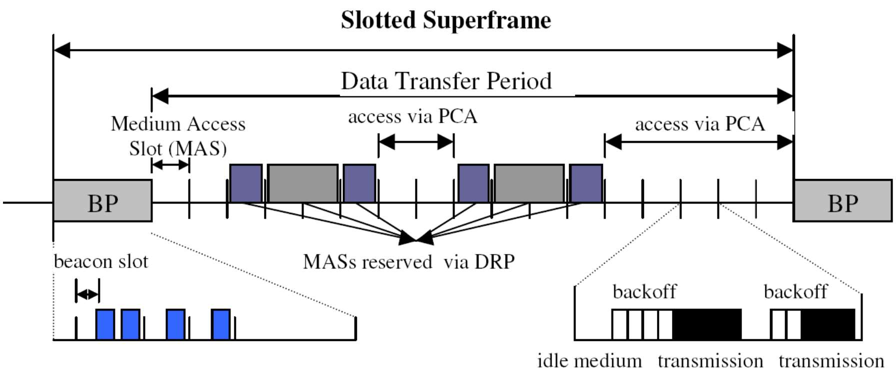

Fig. 2. WiMedia MAC Superframe Structure.

sense multiple access with collision avoidance (CSMA/CA) protocol called Prioritized Channel Access (PCA).

In the asynchronous traffic transmission scheme of the AMT, each N-screen device broadcasts and shares the order of PCA reservations by including a new PCA IE into its beacon. In Fig. 3 of PCA IE, the Element ID field denotes that function of this IE is PCA IE. The QL (Queue Length) field indicates the length of queue where the asynchronous packets wait to be transmitted. And the AC (Access Category) field means the priority of transmission of asynchronous traffic in its device. According to received values of these fields from all neighbor devices, the transmission order of its asynchronous N-screen packets is determined by itself to be set the higher at a larger QL when the ACs are the same with others. And the transmission order is set higher at a smaller beacon slot number when the QLs are the same with others.

A DRP Availability IE in the D-MAC indicates current status of MAS reservations in a superframe. Owners of MAS reservations are 1-hop neighbor devices around of the reference device. DRP Availability IE has a bitmap field with 256 bits. Each bit denotes one MAS and indicates the availability of reservation by its neighbor. If it can be reserved, it has '1' value, or it has '0' value. This DRP Availability IE made by accumulating all DRP IEs from all neighbor devices [3-4].

Fig. 4 shows an example of current resolution of 2-hop range DRP reservation conflicts. In Fig. 4(a), a DRP reservation DRP_{DB} has been established between DEV D and DEV B. DEV D transmits data frames to DEV B during the DRP_{DB}

Element ID	Length	Queue Length(QL)	Access Category(AC)
1 octet	1 octet	1 octet	1 octet

Fig. 3. Format of a PCA IE.

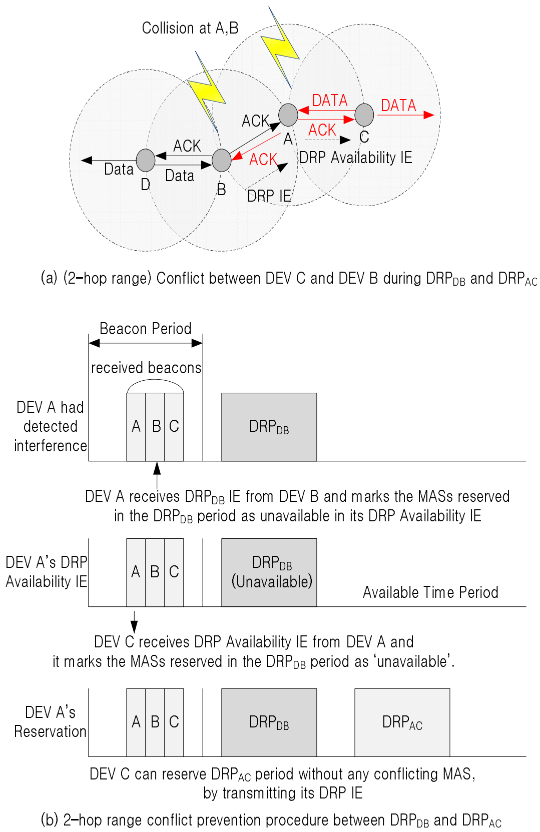

Fig. 4. The example for the current resolution of 2-hop range DRP reservation conflicts.

period. If DEV C begins to negotiate with DEV A to transmit data frames to DEV A during DRP_{AC} period with overlapping MASs, a DRP conflict happens between DRP_{DB} and DRP_{AC}. In the Wi-Media D-MAC, this problem is solved by the DRP IE and the DRP Availability IE. Fig. 4(b) shows the current resolution procedures of 2-hop range DRP reservation conflicts. If DEV D and DEV B succeed in the DRP_{DB} negotiation, DEV B broadcasts the information about DRP_{DB} period by transmitting its DRP IE. From information of received DEVB's DRP IE, DEV A marks DRP_{DB} period as unavailable in its DRP Availability IE. Fig. 5 shows the format of DRP Availability IE. It is used by a device to indicate its view of the current utilization of MASs by 1-hop neighbors in the current superframe. The DRP Availability bitmap field

Element ID	Length (=N)	DRP Availability Bitmap
1 octet	1 octet	N octets (0~32)

Fig. 5. Format of a DRP Availability IE.

is 256 bits long, one bit for each MAS in the superframe. Each bit is set to'one'if the corresponding MAS is available for a DRP reservation in 1-hop range area from the device or each bit is set to 'zero' otherwise. A device's DRP Availability IE is made by receiving and combining all DRP IE s from its 1-hop range neighbor devices. If DEV C receives the DRP Availability IE from DEV A, then, the DEV C can know that the DRP_{DB} period is unavailable for DEV A, and in DRP reserving DRP_{AC} period, it excludes those MASs belonging to the DRP_{DB} period. Therefore, DRP reservation conflicts between the 2-hop range hidden devices (i.e. DEV B and DEV C) are prevented by transmitting the DRP Availability IE. In Fig. 4(a), the case where DEV C receives the DRP Availability IE from DEV A means that the DEV C receives information of 2-hop range devices' DRP reservation status.

The multicast resource reservation scheme of the AMT uses a new Multicast Availability IE without use of the DRP Availability IE. This IE indicates current status of MAS reservations in a superframe, but if a device is a multicast receiver, its reserved multicast MASs in its DRP IE can be reserved by the reference device with 1-hop distance. Therefore, corresponding bits in the Multicast Availability IE have ones as shown in Fig. 6. This feature is different to the previous DRP Availability IE. The reason why Multicast Availability IE is proposed is because the ACK frame transmissions are not required for multicast transmissions in P2P N-screen services. Consequently, if there are multicast transmissions in P2P N-screen services, AMT Multicast Availability IE increases the number of available MASs more than the previous DRP Availability IE.

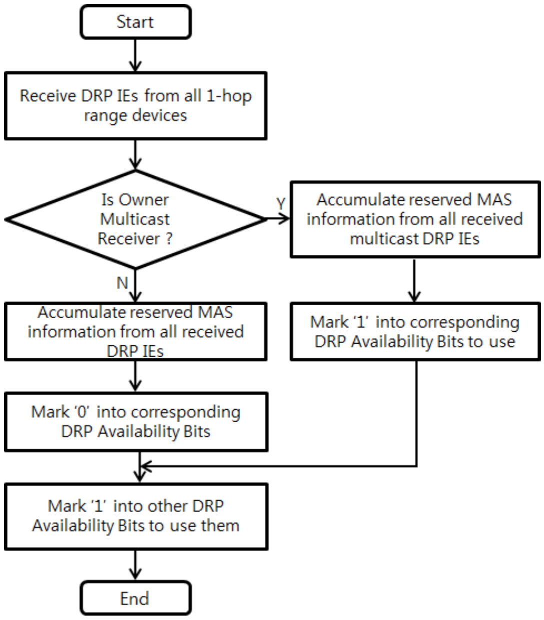

Fig. 6. Generation procedure of proposed AMT Multicast Availability IE.

3. PERFORMANCE EVALUATION

We designed the AMT in P2P N-screen services and simulated it for performance evaluation between a wireless IPTV and a personal video recorder [5-7]. In the simulation, the single 2-hop AMT network size is 5m*5m with 20 D-MAC devices and WiMedia PHY/MAC Parameters are set up [3-4]. For this simulation, we denote a number of MASs in own DRP reservations of the reference device as DRP_{own}. We set this DRP_{own} equal to 50 MASs. And a number of MASs in DRP periods reserved by 1-hop neighbor devices of the reference device is denoted as $R_{1\text{-hop}}$. Also, a number of MASs in DRP periods reserved by 2-hop distant devices from the reference device is denoted as $N_{2\text{-hop}}$. On the other hand, each 1-hop distant device from the reference device has a m_{In} (Multicast and PCA Interference) probability. The m_{In} means a probability with which a device generates multicast DRP and PCA traffic to its 1-hop neighbor device.

Fig. 7 shows throughputs of N-screen devices at each system according to each D-MAC frame size. In this experiment, the $R_{1\text{-hop}}$ is set equal to 40 MASs and the $N_{2\text{-hop}}$ is set equal to 50 MASs. When the m_{In} is set equal to zero, the 1-hop neighbor devices from the reference device do not generate multicast DRP and PCA data packets. Thus, in this case, the 1-hop multicast DRP and PCA interference does not exist. As a result, the throughput of N-screen devices shows the highest value. But, when the m_{In} is set equal to 50%, the 1-hop multicast DRP and PCA interference increases. In this case, as shown in Fig. 7, Multicast-only scheme without PCA IE increases throughput more than the conventional WiMedia D-MAC. Because ACK frame transmissions are not required for multicast transmissions in P2P N-screen services. Using this property, this Multicast - only scheme expands the number of time slots available for multicast reservations.

On the other hand, the AMT scheme increases throughput more than the Multicast - only scheme irrespectively of the frame size. This result explains that reduction of conflicts between PCA asynchronous packets at the AMT increases throughput more than the Multicast-only scheme

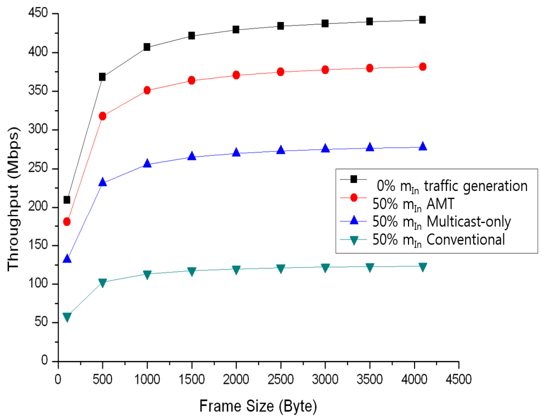

Fig. 7. Throughputs of N-screen devices at each system according to each D-MAC frame size ($R_{1\text{-hop}}$=40MASs,$N_{2\text{-hop}}$=50MASs).

by broadcasting and sharing the order of PCA reservations through including PCA IEs into beacons. Fig. 8 shows throughputs of N-screen devices at each system according to each PHY data rate. In this experiment, the m_{In} is set equal to 50% and the $N_{2\text{-hop}}$ is set equal to 50 MASs. As shown in Fig. 8 and Fig. 9, both systems indicate that DRP reservation conflicts increase largely in proportion to the value of $R_{1\text{-hop}}$. Thus, throughputs of N-screen devices decrease proportionally to the value of $R_{1\text{-hop}}$. On the other hand, the AMT scheme increases throughput more than the Multicast - only scheme, by using the PCA IE, irrespectively of the

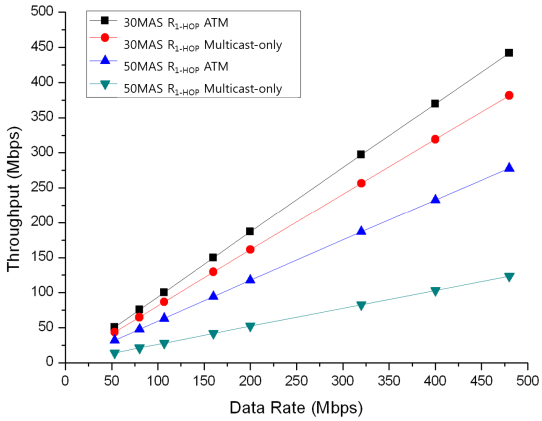

Fig. 8. Throughputs of N-screen devices at each system according to PHY data rate (mIn=50%, $N_{2\text{-hop}}$=50MASs).

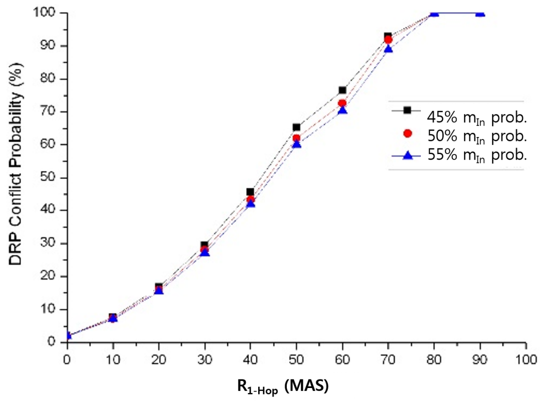

Fig. 9. DRP conflict probability of N-screen devices at AMT system according to values of $R_{1\text{-hop}}$ ($N_{2\text{-hop}}$=50MASs).

PHY data rate.

4. CONCLUSIONS

N-screen is a demand of future to support multimedia multicasting, content sharing, content mobility, media scalability, media synchronization, and seamless mobility. N-screen service transmits the service content via a wired or a wireless network. The increase of the requirement for high quality multimedia service causes the increase of network bandwidth required. Thus, the service providers should obtain the technology that provides the highest quality content seamlessly. In this paper, a WiMedia Distributed-MAC protocol is adopted for the seamless N-screen wireless service. The proposed AMT scheme minimizes the length of idle period at PCA and the length of reserved MASs for multicast N-screen multimedia transmissions. However, it does not require the additional channel information that generates signaling overhead. By applying these research results of wireless N-screen services, an implementation framework for the next-generation smart communication system can be configured.

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