Integrated 2-Hop Communication for the HiperLAN/2 Infrastructure Mode

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Abstract

In this paper a concept is presented which introduces a new element called forwarding mobile terminal (FMT) to the HiperLAN/2 (H/2) world. The FMT is designed to provide users in uncovered areas with access to a fixed network by providing an intermediate hop. The FMT is introduced in a way that it is backward compatible to existing H/2 equipment. The FMT is a modified H/2 mobile terminal which only needs different software, but no additional transceiver. The concept is evolved for the H/2 link layers and analysed in its implication onto the quality of service provided to the users.

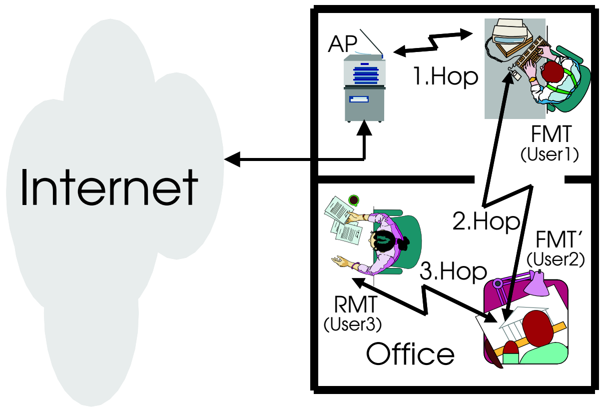

Figure 1. Forwarding Scenario Indoor

1. Introduction

The access to the Internet has become a very important factor in the recent years and it will become even more important in the future. At the same time the Internet goes wireless and systems are upcoming that support high data rates for the wireless access to the Internet.

Figure 1 shows an office environment, where each user is equipped with a wireless terminal. Systems of this type include the *HiperLAN/2 (H/2) system* [4][9][3]. The H/2 system supports typical data rates of 25 Mbit/s. To support these data rates H/2 operates in the 5 GHz band with a bandwidth of 20 MHz per frequency channel.

The radio propagation in these frequency range is very much effected by high attenuation when line of sight can not be guaranteed in an environment, e.g., by walls in offices.

In figure 1 the access to the Internet, resp. the *H/2 access point (AP)* for user 2 and user 3 is provided by a multi hop link via user 1. In the following the equipment of user 3 is denoted as *remote mobile terminal (RMT)*. The term remote differentiates it from a standard *H/2 mobile terminal (MT)*, as the RMT does not have direct access to the AP. User 2 and 1 are forwarding the traffic for user 3 and their equipment is therefore called *forwarding mobile terminal (FMT)*. These FMTs may also operate as conventional MTs. In the shown scenario the services requested by the users are provided by the Internet, therefore no internal traffic except forwarding traffic between the users is observed.

In this contribution a new idea to integrate two or even more hop communication to access a fixed network using the H/2 system is presented. Besides the implementation options the effects onto throughput and the *quality of service (QoS)* parameter delay are evaluated.

2. Implementation of Forwarding in H/2

The main task when supporting forwarding is to separate the different links, i.e., the different hops. A very native approach for an FMT in H/2 would be to glue an AP together with an MT and let the terminals operate on different frequencies. Although this approach seems to be very practical it has the big disadvantage that two transceivers are necessary for an FMT which increases the terminal costs and leads to unsynchronised sub nets. These unsynchronised sub nets show problems to support hard QoS requirements in case of forwarding [7].

In the following a forwarding concept using a time sharing approach is presented which employs only a single transceiver and supports a synchronised access of the RMT which also helps to support QoS for the RMTs.

The proposed concept also provides a solution with minor/no modifications to the existing H/2 specification in its basic implementation. The FMT is simply a new element between AP and MT, which is seen as an AP by the MT and an MT by the AP. The concept operates with already existing scheduling algorithms although scheduling algorithms developed for forwarding are expected to further improve the efficiency of the concept.

2.1. Medium Access Control Sub Frame

The natural place to integrate a time sharing forwarding concept in H/2 is the *medium access control (MAC)* sub layer, as this layer is responsible for a time division multiple access to the shared medium. All new access techniques have to be at least aligned with existing mechanisms.

Figure 2 shows the developed MAC scheme. In the upper part the conventional *H/2 MAC frame (MF)* is displayed with its typical BCH, FCH, ACH, downlink, uplink phase and RCH [5]. As it is a requirement to support regular MTs, a sub frame is generated by the FMT on the second hop. This sub frame has the same structure as the MF to allow access for conventional terminals. The only difference between MF and sub frame is the shortened length of the sub frame. As the AP also not know the existence of FMTs the second hop has to be placed in a phase of the MF which is neither occupied by the AP nor by other MTs. Therefore the sub frame is placed in a separate uplink phase which is controlled and re-scheduled by the FMT. The AP considers the communication of the FMT as uplink, but as the parts of the sub frame do not conform to the conventional uplink, these parts are ignored by the AP.

All parts of the sub frame are extended by the term *forward (F)*. The data of the MF is logical forwarded by the FMT to its connected (R)MTs. During F-FCH, F-ACH, F-DL, F-UL and F-RCH the communication between FMTs and RMTs takes place in exactly the same manner as for the conventional communication.

The proposed MAC frame may also be applied recursively to support far remote terminals, i.e., a new sub frame for the third hop is nested into the sub frame of the second hop.

3 FMT System Integration

Maintaining the principles for the construction of the sub frame a possible software structure for the FMT is depicted in figure 3.

The block denoted as *sub frame access point (SF-AP)* is responsible for the generation of the sub frame. The procedures and routines used in this block are derived from the

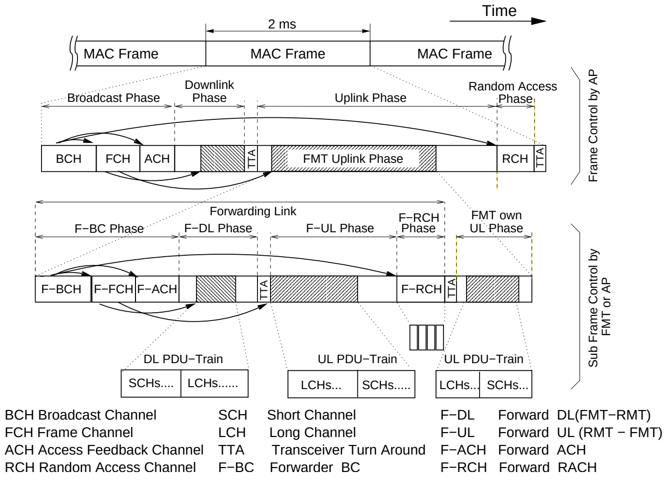

Figure 2. H/2 MAC Frame including Forwarding Sub Frame Structures

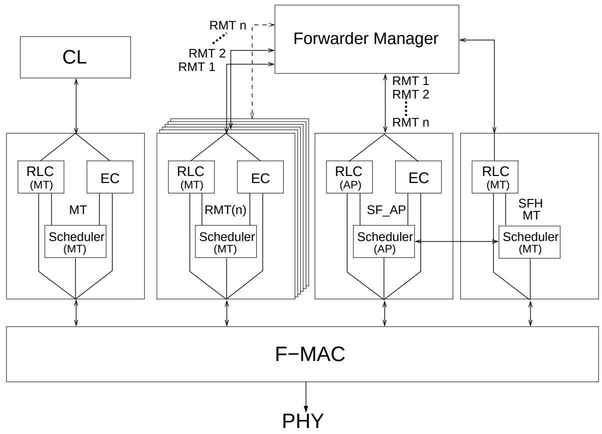

Figure 3. FMT Software Structure

standard AP block. The only difference is the shortened MF to be used as sub frame. The block *sub frame handler (SFH)* is responsible for capacity allocation for the sub frame. As it appears to the AP as a conventional MT it is derived from an MT block. Via a link to the scheduler of the SF-AP it announces the length and starting point of the sub frame to the SF-AP. Each RMT(n) block is a representative for an RMT associated with this FMT and handles the traffic on the first hop towards the AP. The RMT blocks have the same structures as conventional MTs. The Forward Manager connects all blocks necessary for the FMT functionality. Inside the Forward Manager the data and signalling flows between the blocks are coordinated. On the left in figure 3 the structure of an MT is integrated. This block is responsible for the communication for the FMT user and acts completely independent to the rest of the FMT. Therefore the FMT's own uplink phase as depicted in figure 2 is reduced to the SCHs which are used as resource requests for the sub frame.

3.1 RLC Signalling

An important topic for the integration of the FMT concept is the correct handling of signalling in a system setup. The integration of signalling in the FMT is done keeping in mind the concept already applied for the MAC layer, i.e., reusing the available standard H/2 system to the extend possible. The RLC blocks in the FMT software structure are derived from the standard procedures available. The already introduced Forward Manager is responsible for organising these signalling flows. In the following the resulting signalling flows for a two hop system are shown.

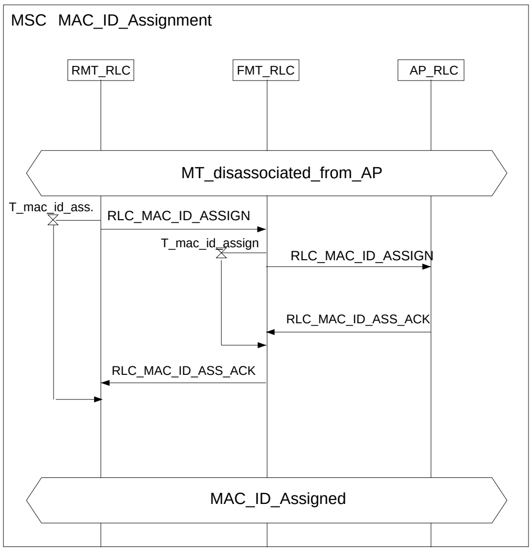

Figure 4. MAC-Id-Assign

Figure 4 shows the MAC-Id assignment for the MAC-Id to be used between an RMT and the FMT and the MAC-Id for the RMT representative in the FMT which is used for the communication between AP and FMT. The MAC-Id to be used by the FMT to request capacity for the sub frame is assumed to be already agreed between the FMT and the AP.

The procedure is triggered by the RMT with a request to assign a MAC-Id. This request is then followed by signalling to the AP. The signalling is sequenced in time. Keeping in mind the additional delay for multi hop communication, problems with the timer T-mac-id-ass may occur especially in multi hop environments. Although for two hop communication no problems are expected.

Another important system aspect is the support of handover with this concept. Apart from the handover scenarios also known to the standard H/2 system a set of new handover types apply. These new handover types result from the handovers when an MT is becoming an RMT or vice versa. Figure 5 shows the indoor scenario of an MT which was associated to an AP but is then entering the shaded area and can only be supported by an FMT in this area. The FMT is assumed to continuously generate a sub frame.

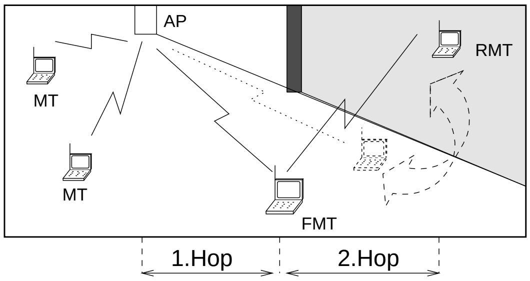

Figure 5. Handover Scenario

The proposed resulting signalling is shown in figure 6. The procedure is similar to the H/2 network handover.

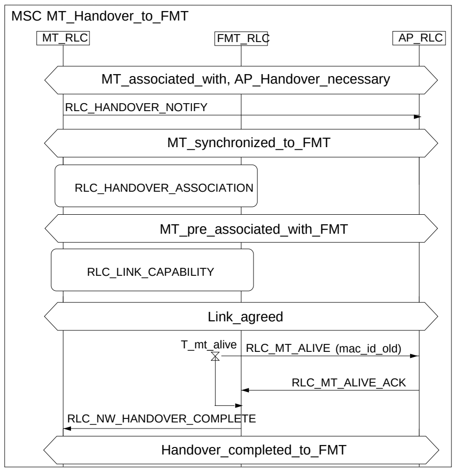

Figure 6. Handover Signalling

The MT, which becomes a RMT during this process, notifies the AP about the handover and then associates to the FMT using standard H/2 signalling. There is also no other possibility as to use the existing signalling because the RMT is a conventional H/2 MT. After the association FMT and (R)MT exchange the link capability signalling. Once the link is agreed the FMT starts to resume the communication with the AP on behalf of the (R)MT. This is the reason for using the old MAC-Id of the (R)MT which is exchanged between (R)MT and FMT during the handover signalling.

4 Performance Analysis

In the following the performance analysis of throughput and delay is presented. The analysis is mainly affected by the sub frame structure. The RLC procedures are assumed to have taken place and build up the necessary connections.

4.1 Throughput

Additional capacity for the organisation of the sub frame and for user data transfer on additional hops is needed. This decreases the overall capacity available for user information. The maximum available capacity also depends on the H/2 physical (PHY) mode [6] used on the respective links.

Figure 7 shows the capacity available for user data depending on the number of FMTs supported in a radio cell (throughput for standard system see [1]). Each FMT is expected to serve one RMT, so a star configuration is formed. The graphs are parameterised with the chosen PHY mode. Three graphs use the same PHY mode on the first and second hop, while one graph shows a combination of different PHY modes on the hops. This configuration will appear in a situation where the link adaptation decides to use different PHY modes, e.g, if the attenuation between AP and FMT is different to the attenuation between FMT and RMT. This unsymmetrical case was also chosen for simulation [2] and verified.

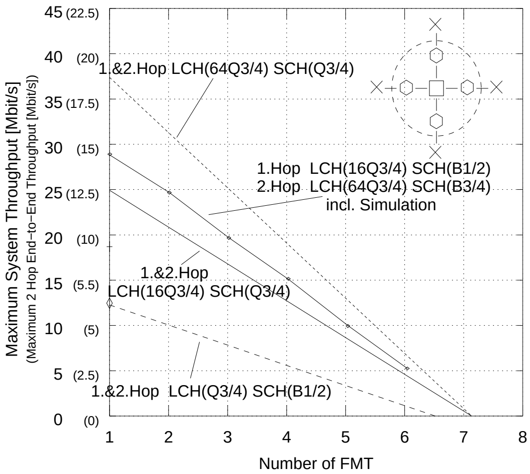

Figure 7. Use of different H/2 PHY Modes on 1./2. Hop

The maximum end-to-end throughput decreases significantly with an increasing number of FMTs. More than six active FMTs in a cell result in almost no capacity available for user information transfer. So the concept seems to be especially beneficial for cases of one to three FMTs as the capacity lost for organising the sub frame is not too high.

Additionally to the maximum end-to-end throughput the graphs are scaled according to the maximum system throughput, which is the sum of all data traffic handled in the system on all links, i.e., two-hop end-to-end communication counts twice. The maximum system throughput also gives a figure for the capacity which is available for MTs in the base cell when a sub frame without traffic is supported, i.e., the loss for organising sub frames. In real cells the traffic will be a mixture of one hop and two hop traffic. For three hop traffic and nested sub frames the same graph for the maximum system throughput applies, as no additional effect results from the nested sub frames. The FMT served by an FMT is just an additional FMT. On the other hand the data for the user has to be transmitted an additional hop, so the end-to-end capacity is once more reduced, irrespective from the fact that an additional delay for the three hop user traffic is expected (see below).

4.2 Delay

Besides the throughput the delay distribution is an important quality of service aspect. In the following the delay for one hop , two hop and as the sub frame principle can be applied recursively also three hop communications is analysed. To prevent the system from overloading effects a total system load of and below 15 Mbit/s. A Poisson arrival process was used for the simulations.

Figure 8 shows the complementary distribution functions for the different hops in downlink direction.

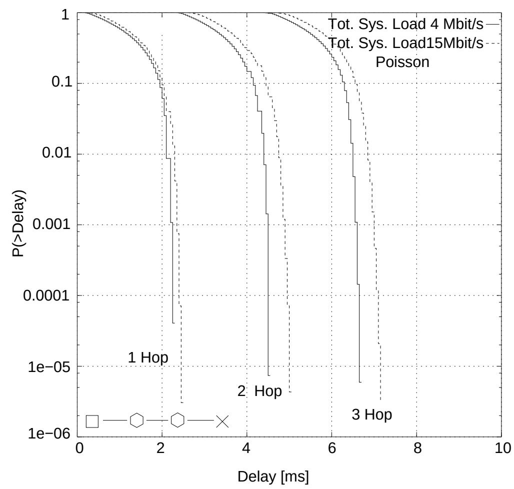

Figure 8. Downlink Delay Distribution for 1/2 and 3 Hop Communication

Each additional hop in our simulation leads to an additional delay of about one MF, i.e., 2 ms. The shift in the graphs for 4 and 15 Mbit/s is due to the fact that in the 4 Mbit/s case the data is transferred at the beginning of a frame whilst in the 15 Mbit/s case the frame is more filled up and the data has to wait longer for transfer.

Figure 9 shows the uplink delay for the data. As for the downlink case the uplink transfer needs one additional MF, i.e., 2 ms per hop compared to the one hop transfer. As already known for the standard H/2 system [1] the delay in uplink direction needs one more MF as uplink capacity has to be requested before user data is transferred.

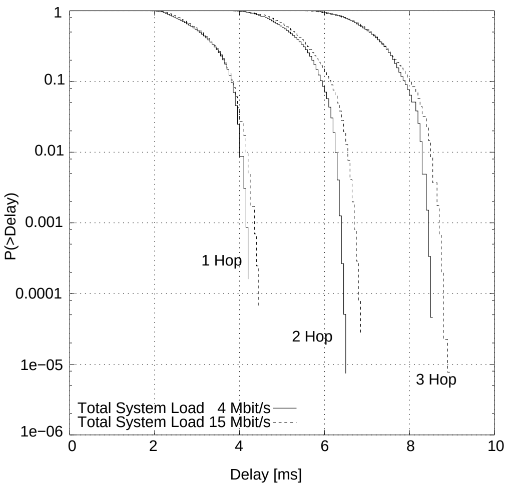

Figure 9. Uplink Delay Distribution for 1/2 and 3 Hop Communication

5 Conclusion

In this contribution a concept for an integrated multi hop communication for the *HiperLAN/2 (H/2)* system is presented. The concept is intended to be used for the infrastructure mode of H/2 as it aims to provide far remote users with a cost efficient access to a fixed network without the need to invest into fixed infrastructure. The concept is especially beneficial for indoor environments where high attenuation by walls can be expected and a planned setup is used [8].

The multi hop communication is supported by a new element called *forward mobile terminal (FMT)* which is equipped with an extension to the existing medium access control of H/2 and is characterised by a sub frame structure that supports already existing H/2 APs and MTs. The sub frames are integrated into the existing structure in a way that no additional transceiver hardware compared to a conventional MT is needed for the FMT. As this only can be applied on a time sharing basis the data on the distinct hops has to be transferred sequentially.

The concept has a number of effects onto the quality of service which is analysed in this contribution. Besides the integration on medium access control layer the FMT has to be logically integrated into the H/2 system concept. The software structure and the signalling uses already existing H/2 blocks and procedures which are extended to support the presented concept. The reuse of blocks and procedures on the other hand supports the compatibility with existing H/2 equipment.

In the presented concept the use of a single transceiver and the backward compatibility to already deployed equipment are the key design criterions. On the other hand for future implementations it is possible to further enhance the concept within the existing specification by applying novel scheduling algorithms to newly deployed access point and let the access points hereby support multi hop communication.

6 Acknowledgment

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