Supporting Cost Efficient Public 5GHz-W-LAN Roll Out with a Multi Hop HiperLAN/2 Concept

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1 Abstract

This contribution highlights the possibilities and service characteristics for a cost and time efficient roll out for public wireless local area networks providing wide coverage in urban areas. The HiperLAN/2 (H/2) multi hop concept is based on intermediate relay stations. This eliminates the need for intensive cabling, reducing the costs. The H/2 multi hop concept introduces a new element called forwarding mobile terminal (FMT) to the H/2 world. The FMT is a modified H/2 mobile terminal which only needs different software, but no additional transceiver. In city scenarios the forwarding concept allows a fast roll-out while limiting the cabling cost and providing a reasonable user service in a large service area.

2 Introduction

Internet access is becoming increasingly important. Furthermore, the trend is towards the wireless world, providing high data rates public access to the Internet via wireless devices. Figure 1 shows users in private and public environments, where each user is equipped with a *HiperLAN/2 (H/2)* wireless terminal. The radio propagation in frequency ranges used by H/2 (5 GHz) is very much effected by high attenuation when line of sight can not be guaranteed in an environment, e.g., due to walls.

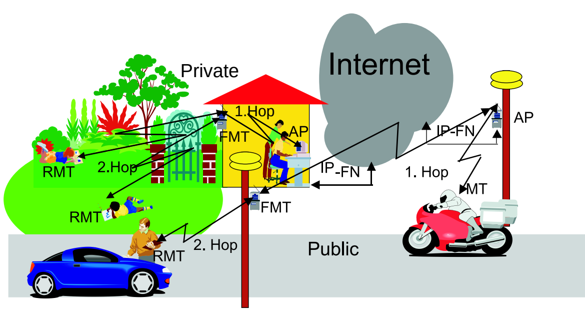

Fig. 1: Multi Hop Wireless Internet Public/Private

In figure 1 the access to the Internet, resp. the *H/2 access point (AP)* for some users is provided by a multi hop link via an intermediate station. The equipment of these remote users 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 fixed network. Intermediate stations that are forwarding the traffic for remote users are called *forwarding mobile terminals (FMT)*. This contributions will highlight the possibilities and service characteristics for a cost efficient roll out for public wireless local area networks providing wide coverage in urban areas. The *HiperLAN/2* (H/2) multi hop concept for H/2 is used to save cost intensive cabling and employs FMTs instead.

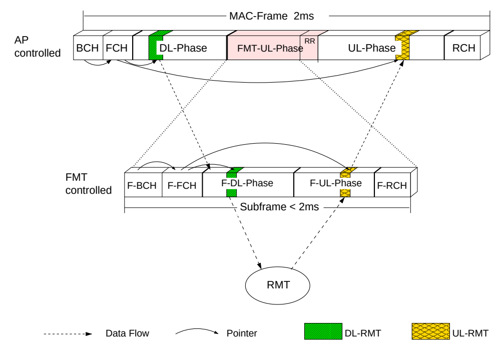

Fig. 2: H/2 MAC Frame including Forwarding Sub Frame Structures

3 Implementation of H/2 Forwarding

A time sharing approach for forwarding is used that employs only a single transceiver and provides a solution with minor/no modifications to the existing H/2 specification. The FMT is simply a new element between AP and MT, which is seen as an AP by the MT and as an MT by the AP. Figure 2 shows the MAC scheme developed. In the upper part the conventional *H/2 MAC frame (MF)* is displayed with its typ-

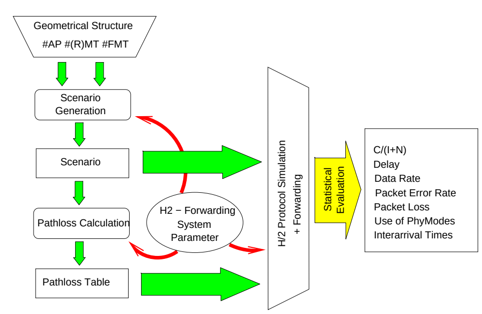

Fig. 3: MADCAT System Simulator Principle

ical broadcast phase (BCH, FCH, ACH), downlink, uplink phase and random access (RCH) [1]. As it is a requirement to support regular MTs, a *sub frame (SF)* is generated by the FMT in its own uplink on the second hop. This SF has the same structure as the MF to allow access for standard H/2 terminals.

The simulations in this paper were done with the system simulator MADCAT which structure is shown in figure 3. With a geometrical description of the scenario, H/2 system parameter, the number and the position of the simulated entities a simulation scenario is generated. From the scenario the pathloss between all entities is calculated and stored in a table. Scenario and pathloss tables are then processed in a complex protocol simulation followed by a statistical evaluation which produces the characteristic system value.

4 Comparison of Standard and Forwarding H/2 in Open Space

In this section the system performance of the standard H/2 with the H/2 forwarding approach is compared. To get reliable feasibility statements of both approaches it is essential to take the interference situation into account. For the calculations the following attenuation model was taken into account [2]:

$$P_r = \begin{cases} P_s \cdot g_s \cdot g_r \left(\frac{\lambda}{4 \cdot \pi}\right)^2 \cdot \frac{1}{d^\gamma} & \text{for } d > 1m, \\ P_s \cdot g_s \cdot g_r \left(\frac{\lambda}{4 \cdot \pi}\right)^2 & \text{for } d \leq 1m. \end{cases} \tag{1}$$

The resulting *Carrier (C)* to *Interference (I)* and *Noise (N)* - ratio is denoted by:

$$\frac{C}{I+N} = \frac{P_C}{N + \sum_{i=1}^{6} P_{I_i}} \tag{2}$$

with:

d : Distance between Sender and Receiver,

P_s : Sending Power,	P_r : Received Power,
g_s : Antenna Gain Sender,	g_r : Antenna Gain Receiver,
λ : Wave Length,	γ : Attenuation Factor,
P_C : Power Carrier,	P_{I_i} : Power Interferer i,
P_N : Noise Power.	

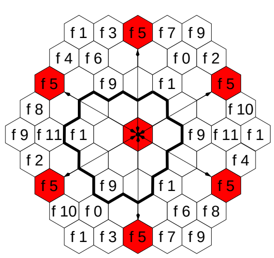

Fig. 4: Co-Channel Interference Scenario, Cluster Size N=12

In figure 4 the co-channel interference reference scenario for a cellular system setup using 12 frequencies is displayed, i.e. setup with cluster size $N = 12$. The shaded cells operate on the same frequency and cause co-channel interference. For the evaluation the nearest 6 co-channel interferers of the inner cell are taken into account.

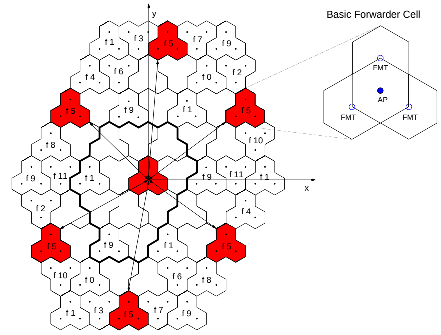

Fig. 5: H/2 Cellular Concept with 3 FMTs per Cell, N=12

The introduction of the new forwarding terminal FMT extends the cell depending on the number of FMT. In figure 5 at the right top corner the cell changing is displayed for the use of 3 FMT. In [3] it is already shown that the maximum gain for this concept in open space scenarios is achieved, if there are three forwarders which have no overlapping areas. The cell area is increased to a factor of 3 with the same number of wired Access Points. Due to the new cell shape the scenario, shown in figure 5, is slightly distorted. The positioning of the basic forwarder cells with twelve frequencies, is done analog to a standard cellular cluster of size twelve.

Table 1 summarizes the overall system simulation parameters. The association of terminals to either AP or FMTs is done based on the following assumption: up to the cell boundary (50m) the MT is associated with the AP. Outside this area the MT is associated with the FMT and operates as RMT (two-hop communication).

Parameter	Setting
Cell Radius Basis Cell	$50m$
PhyMode	acc. Link Adaptation
Scheduling	Exhaustive RR / Non ERR
Traffic Class	Best-Effort

Table 1: System Simulation Parameter

In figure 6 the maximum reachable throughput seen by an (R)MT is shown. Displayed are the throughput results with a cluster size N=3 and N=12 for the H/2 standard as well as for the forwarding approach. With an increasing number of frequencies the maximum transmission rate rises, as the co-channel interference is reduced due to the higher distance between the interfering stations.

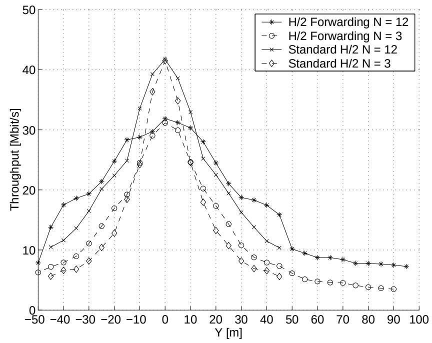

Fig. 6: Maximum Throughput Comparison from Standard H/2 with the Forwarding Concept

The forwarding approach can not reach the maximum throughput of standard H/2 in the cell center due to the additional frame signalling as shown in figure 2. A higher throughput within the basis cell area at an AP for approx. 10-50m is observed for the forwarding deployment compared to the standard approach. With introduction of FMTs the cells are growing thus the mean distance to the co-channel cells is increasing as well, for the same virtual cluster size. This leads to an interference decrease.

Another important point is the maximum throughput for terminals using a two hop communication at a distance above $50m$. Depending on the cluster size the maximum throughput for the two-hop communication could be seen between 4 Mbit/s and 9 Mbit/s (cf. figure 6). Compared with the throughput at the basic cell border at $50m$ where the FMT is placed the rate in the forwarder supported area is similar. At this point the FMT has the same connection quality towards the AP as an MT. Beyond this point the terminal can be supported by an FMT at the border of a cell. The connection quality between RMT and FMT is at least the same as the quality between FMT and AP hence the throughput in the FMT covered area is more stable than in the cell center.

The same effect can be seen in figure 7. In this figure the available throughput capacity is shared among 60 terminals uniformly distributed in the cell area. The rate seen by each

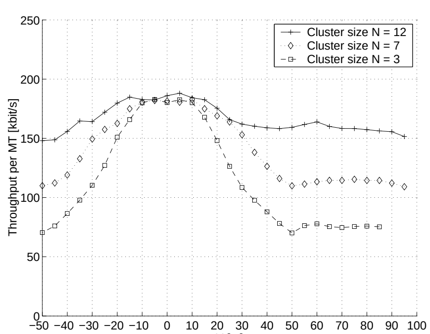

Fig. 7: Distribution of Simulated Throughput per MT in a Forwarding Scenario, 60 MTs simultaneously (*heavy load*)

terminal is around 100kbit/s (*heavy load/worst case assumption*). With increasing the cluster size the interference is decreased and the available rate at the cell border where the FMT is placed, rise. Therefore the FMT is capable to support the RMT with approximately the same rate as the FMT is connected.

Cluster Size $N =$	3	7	12
Standard H/2	8.24 Mbit/s	11.73 Mbit/s	14.57 Mbit/s
Forwarding H/2	4.64 Mbit/s	5.82 Mbit/s	7.75 Mbit/s

Table 2: Summary of Total System Throughput (ERR), 60 simultaneously active MTs

Finally in table 2 the system wide maximum throughput is shown. Here the impact of the additional forwarding signalling could be seen. The signalling overhead reduce the system throughput by around $50\ \%$ due to the high number of active terminals but the covered area is enlarged to a factor of 3. The overall supported service will be still sufficient for roll out purpose.

5 Standard H/2 in a Manhattangrid

The most promising area to deploy a Wireless LAN like H/2 seems to be an urban area. Therefore the so called 'Manhattan Scenario' as defined in UMTS [4] is taken as basis for further investigations. As the H/2 is not designed for very large cells a setup with a block size of $75m$ x $75m$ with a street width of $15m$ is used.

In figure 8 three possible deployment of standard H/2 in urban area are shown. Scenario (a) shows a distribution of cells, where the Access Points are located between two blocks with a shift from street to street. This scenario is similar to the original UMTS scenario. Figure 8 (b) is a variation without shift from street to street. In configuration (a) and (b) four frequencies are used. As the heavy attenuation by wall is used to seperate the cells, we assume that each wall has an attenuation of 11.8dB. In deployment (c) the APs are placed at a crossroad hence each AP is able to

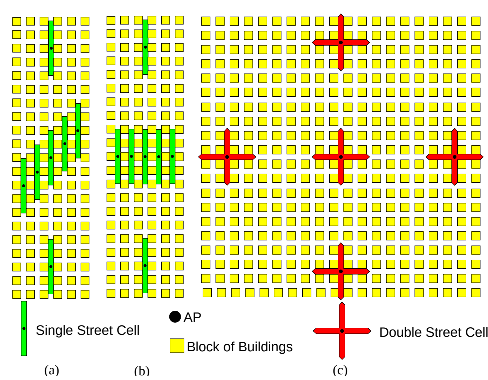

Fig. 8: Frequency Re-Use Pattern for Standard H/2

cover a higher area but this scenario needs a minimum of eight frequencies. Due to walls with high attenuation, the interference to be taken into account for the system simulations, only comes from cells and devices having *line of sight* (LOS) conditions.

Scenario	Freq.	Cell Size	Throughput	
			NERR	ERR
(a)	4	$5400\ m^2$	7.95 Mbit/s	19.0 Mbit/s
(b)	4	$5400\ m^2$	7.45 Mbit/s	18.0 Mbit/s
(c)	8	$10350\ m^2$	7.71 Mbit/s	18.1 Mbit/s

Table 3: System Simulation Parameter and System Throughput for 60 simultaneously active MTs

In table 3 the maximum reachable throughput is summarized. The scenarios in figure 8 are evaluated with an exhaustive round robin (ERR) scheduling and with Non ERR (NERR) scheduling. ERR scheduling minimizes the signalling overhead originated by a high number of connections but increases the packet delay. NERR needs more signalling overhead resulting in a lower system throughput but provides an constant service for each MT over the covered cell area (cf. figure 9).

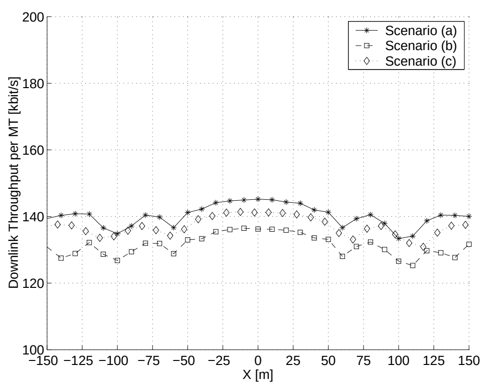

Fig. 9: Standard H/2 Throughput per MT in Manhattengrid, NERR scheduling and 60 simultaneously active MTs

6 H/2 Forwarding in a Manhattan Scenario

In figure 10 a setup is shown where each cell consists of one AP and 4 FMTs. The attenuation by walls leads to a situation where the interference results only from cells that are in LOS conditions to the central cell. Therefore there are four interfering co-channel cells that are taken into account in the following. Only two frequencies are used in this scenario.

In figure 11 the results for a single terminal in a heavy load simulation is shown, with 60 simultaneous active terminals and NERR scheduling at cluster size N = 3. The figure

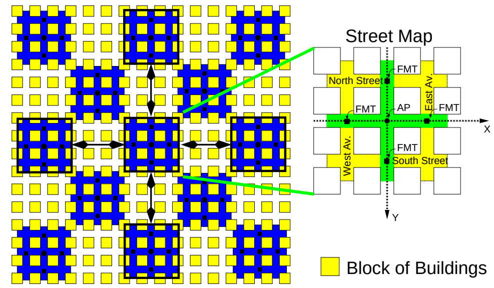

Fig. 10: Frequency Re-Use Pattern for H/2 Forwarding

shows the central street results marked with arrows to the position at $X = \pm 90m$ and the throughput results in in the side streets with the FMT located in the middle ($X = 0m$). Roughly the same throughput as near to the FMT is provided to an MT along any streets supported by an FMT. This behavior is identical to the open space forwarding scenario.

Finally in figure 12 the delay distribution is shown. It can be clearly seen which parts of the scenario are supported with a second hop. Users supported by a second hop will experience an additional delay as their data has to be transmitted twice. The difference between the different streets reflects the order the FMTs are scheduled. The crossing of the side streets can be easily identified, as the terminals on the crossing belong to two streets and are interpolated for each individual street. The FMTs can be identified in the central street and avenue at the crossroad with the side streets.

In table 4 the reachable throughput depending on the cluster size is shown. Comparison between table 4 and the standard H/2 table 3 shows the expected: the forwarding scenario has to share the resources for different hops. Therefore the possible throughput is much lower. The forwarding on the other hand can operate with only two frequencies. This makes the initial setup very easy. With the forwarder concept it is possible to support a much higher area without the need to install APs and their cabling.

Additionally table 4 shows the throughput values for dif-

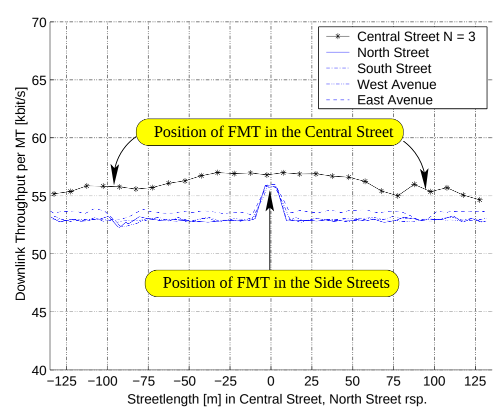

Fig. 11: Forwarding H/2 Throughput per MT for Manhattan Scenario, 60 simultaneously active MTs

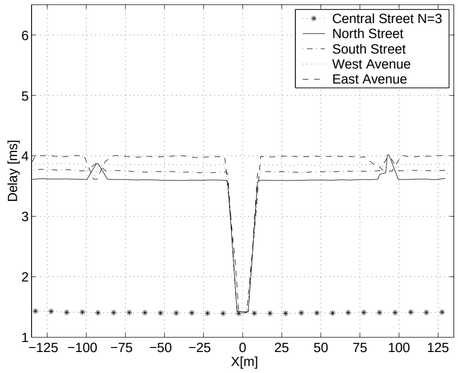

Fig. 12: Delay Distribution Downlink for the Manhattan Scenario: 5 Mbit/s system load (*low load*), 10 active MTs and ERR scheduling

ferent scheduling algorithms. Obviously the NERR algorithm suffers from the high signalling overhead. But NERR scheduling offers a constant service for the whole cell including the RMT (cf. figure 11).

Cluster Size	NERR	ERR	ERR g_r=11.8dB
$N = 2$	2.88 Mbit/s	6.38 Mbit/s	10.8 Mbit/s
$N = 3$	3.27 Mbit/s	8.39 Mbit/s	12.0 Mbit/s
$N = 4$	3.44 Mbit/s	10.63 Mbit/s	12.6 Mbit/s

Table 4: Reachable Throughput for H/2 Forwarding, Cell Size: $22255m^2$, 60 simultaneously active MTs

7 Further Enhancements

There is a number of options that can be used to increase the capacity in a forwarding system. The third column of table 4 shows the throughput possible if directed antennas with $11.8dB$ gain are used between AP and FMTs. Another option is to use two or more frequencies in a forwarder cell simultaneously. Furthermore in figure 13 an advanced forwarder scheduling pattern (*AFSP*) is displayed. Each FMT gets successively the right to transmit the own SF in a separated MF. To serve all 4 FMTs this AFSP needs 4 MFs

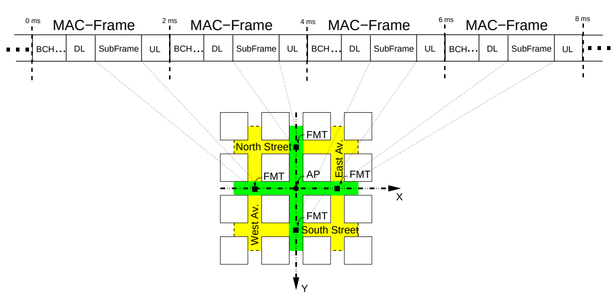

Fig. 13: Advanced Forwarder Scheduling Pattern (AFSP)

hence the forwarder signalling overhead is minimized. The system throughput increases but also the mean delay distribution on the second hop raises. This AFSP enables a provider to cover streets with different priorities i.e. favour the central streets.
A further option is to exploit the seperation caused by the attenuation of the blocks i.e. send data in East Av. and West Av. at the same time. Different setups may be chosen depending on the cost for investment either in devices or cabling, the desired user service and the number of available frequencies. In city scenarios the forwarding concept allows a fast system roll-out while limiting the cabling cost and providing a reasonable user service in a large service area.

8 Conclusion

In this contribution an integrated multi hop communication concept for the *HiperLAN/2 (H/2)* system and the wireless Internet is analyzed for its cellular capabilities, capacity and quality of service for the users. 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 the Internet without the need to invest into fixed infrastructure. The concept is especially beneficial for environments where high attenuation by walls can be expected.

9 Acknowledgement

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10 References

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