BROADWAY – the Way to Broadband Access at 60GHz

M. de Courville[1], S. Zeisberg[2], Markus Muck[1], J. Schönthier[2],

[1]Motorola Labs France, Espace Technologique Saint Aubin
91193 Gif-Sur-Yvette, France
Tel: +33 1 69352518, Fax: +33 1 69352501, email: Marc.de.Courville@crm.mot.com

[2]Dresden University of Technology, Department of Electrical Engineering and Information Technology, Communications Laboratory, 01062 Dresden, Germany
Tel: +49 351 46332803, Fax: +49 351 46332803, email: zei@ifn.et.tu-dresden.de

ABSTRACT

The IST project BROADWAY aims at proposing a hybrid dual frequency system based on a tight integration of HIPERLAN/2 OFDM high spectrum efficiently technology at 5GHz and an innovative fully ad-hoc extension of it at 60GHz named HIPERSPOT. This concept extends and complements existing 5GHz broadband wireless LAN systems in the 60GHz range for providing a new solution to very dense urban deployments and hot spot coverage. This system is to guarantee nomadic terminal mobility in combination with higher capacity (achieving data rates exceeding 100Mbps). This tight integration between both types of system (5/60GHz) will result in wider acceptance and lower cost of both systems through massive silicon reuse. This new radio architecture will by construction inherently provide backward compatibility with current 5GHz WLANs (ETSI BRAN HIPERLAN/2) and thus, the innovations coming out of this project will be a driver for standardization and spectrum allocation of the next ETSI BRAN HIPERLAN generations.

I. INTRODUCTION

The user throughputs provided by existing 2.4GHz WLAN solutions (IEEE802.11b) and new 5GHz OFDM ones (IEEE802.11a, HIPERLAN/2) are already foreseen as insufficient for providing enough throughput for very dense urban deployment (e.g. hot spot coverage). This is the motivation for the proposal of new wider bandwidth WLAN solutions.

The BROADWAY system concept is presented here. It aims at an extension of the existing wireless local area network (WLAN) technology in terms of capacity and privacy in an evolutionary way while providing additionally ad-hoc network functionalities. In a first section the overall system concept and the main objectives are explained. Then, spectrum issues and several potential scenarios are presented. Closely linked to the latter ones, deployment issues and resulting MAC/DLC functionalities are indicated. After having clarified the project from a system point of view, the following sections i) summarize initial results on suitable base-band parameters, ii) present a suitable and low-cost RF architecture and finally iii) predictions on technological progress in the context of our needs.

II. VISION AND OBJECTIVE

The vision is to extend existing broadband wireless LAN systems for providing a new solution to very dense urban deployments and hot spot coverage while meeting the user expectations in terms of available throughput. Moreover, nomadic terminal mobility in combination with higher capacity, i.e. data rates up to 500Mbps per user, shall be possible. Therefore, an extension of WLAN systems in the 5GHz band by new modes in the unlicensed 59-65GHz bands seems to be particularly suited.

Though current WLAN primarily mainly targets the office and home environments, 5GHz as well as 60GHz systems are seen in beyond 3G scenarios at complementing the wide area cellular infrastructure to provide fast public download capabilities. Thus it is foreseen that high geographical density deployment of such systems will occur in many major European cities, in the near future at least for 5GHz WLANs. Since only a limited amount of radio channels are available for the latter ones, a penalty in terms of the system throughput will occur due to inter-system interference. In many cases the dynamic frequency selection will not be able to resolve this problem. Even applying big 5GHz multi-beam antennas suited for fixed access in outdoor environment will not cost efficiently address this issue. In such cases it will be favorable to have an additional means to offload the 5GHz radio channels from interference for avoiding spectrum congestion while maintaining high data rate throughput.

BROADWAY, IST-2001-32686, is a European research project within the 5th framework for research of the European Community in the Information Society Technologies (IST) research programme. Its approach substantially differs from other research projects finished or just in progress [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12] dealing with such topics as 40 or 60GHz communications, broadband wireless access and/or ad-hoc networking. BROADWAY aims at bridging the 5GHz band and 59-65GHz bands by the following means: A dual frequency hybrid WLAN is conceived such that a smooth evolution from 5GHz OFDM HIPERLAN/2 [13] technology towards 60GHz is granted while preserving backwards compatibility and providing, at the same time, an increased total system throughput of 100 to 500 Mbps. The higher data rates will be achieved by a bandwidth expansion in the 60GHz bands. Leveraging existing 5GHz products for a low-cost 60GHz solution will allow competitive product designs.

In the framework of the project, key parts of the BROADWAY concept will be demonstrated on a specific platform already available containing a large FPGA handling the PHY proposed functions (1.5Mgates) and a fast embedded processor implementing the MAC/DLC protocols together with a dual 5/60GHz QMMIC front-end.

III. SPECTRUM ISSUES

Smulders [14] presents the available spectra in the 60GHz area. In Europe, there are two bands available: 59-63 GHz and 65-66 GHz. However, there is a practically worldwide overlap on the 59-62 GHz band only: still this represents already a 3GHz opportunity!

As presented before, it should be possible to plug standard 5GHz products to the 60GHz front-end in order to create low-cost transceiver devices. Up/Down-converting a HIPERLAN/2 signal at 5/60GHz to 60/5GHz makes this possible. However, the high frequency bands must be chosen such that image frequencies in the transmitter at 5GHz below the carrier frequency, which occur due to the up-conversion stage, lie in bands where spurious emissions are tolerated. In the receiver, intermediate frequencies must be chosen such that no high power emitter lies in neighbouring bands, e.g. radars, etc.

IV. SYSTEM SCENARIOS AND MAC/DLC FUNCTIONALITIES

The following BROADWAY scenarios are considered for the system definition:

(i) Hot spots in a vendor area, trains and stations and cyber-cafes. A very important scenario for BROADWAY application is the coverage of physically well-defined areas in an outdoor very dense urban environment. More than simply a way to provide Internet access anywhere anytime, this is also a requirement from vendors which will attract people to come close to their advertising areas by offering certain radio based services for free. The very exact definition of the area of coverage is necessary in this case and is possible with 60GHz radio small size directional/shaped antennas while the connection of these SPOT terminals with the backbone will be achieved through conventional 2G/3G network.

(ii) High density residential dwellings (c.f. figure 1) and flats. Extending WLAN in the 60GHz range, where radio signals hardly penetrate concrete/brick walls will inherently grant no interference with neighboring cells (e.g. other room/office, other apartment). In areas, where there are good environmental conditions (e.g. line-of-sight) between communicating radio terminals the devices will commute to the 60GHz radio frequency band, which will offload the 5GHz radio resources from data traffic and interference significantly. Neighboring homes will become really private on a physical level.

(iii) Corporate environments. Large office spaces are covered by the 60GHz WLAN. Everywhere else, access to the 5GHz network is possible, for example in small personal offices or meeting rooms.

Table 1 resumes the requirement assumptions for the three cases. As a consequence, a resulting aggregate user data rate of up to 500 Mbps is required.

Case	Density Devices/Surface	User Rate Mbps	Aggregate User Rate, Mbps
(i)	100/100m^2	10-100	500
(ii)	10/100m^2	50-200	500
(iii)	50/100m^2	Application depending	500

Table 1: BROADWAY Scenario Definitions.

In all scenarios, the access points (APs) cover both bands at any moment. The mobile terminals (MTs) address only one of the two bands (5/60GHz) at a time. Hereby, the 5GHz network ensures the continuity of coverage and the centralization of signalling. Very high data rates are achieved through peer-to-peer communications at 60GHz. In case of saturation of the 5GHz band, centralized offloading mechanisms map the 5GHz spectrum to 60GHz through vertical handover (c.f. figure 2) allowing a seamless switching. Since the TDD-TDMA OFDM frame structure of HIPERLAN/2 is kept even at 60GHz, there is the ability to manage ad-hoc networking while yet preserving some level of Quality of Service (QoS).

V. BASEBAND AND RF ISSUES

Two different sets of base-band parameters are to be designed. The first set aims at a BRAN HIPERLAN/2 compatible mode where 5GHz channels are ideally just up-converted to 60GHz; however, some minor modifications are necessary in order to be compliant with the low-cost constraints. Particularly the choice of the carrier spacing is impacted, since 60GHz front-ends are expected to introduce far more phase noise compared to the 5GHz solutions.

The second parameter set defines a completely new mode taking into account latest research results in the OFDM field. It is called HIPERSPOT extension. The base-band requirements are derived from scenario needs and from RF requirements. Important inputs from the scenarios are the user data rates as well as the mobile and environmental mobility leading to time dependent channel variations. Important RF constraints are, for example, the power profile and the length of the impulse response of the 60GHz channel combined with transmitter and receiver filters which determines the length of the OFDM guard interval. Phase noise issues impact the choice of the carrier spacing, which needs to be larger at 60GHz than at 5GHz for low-cost receivers. The user data rate requirements impact the choice of the channel bandwidth and thus the sampling frequency. Short, but spectrally efficient OFDM symbols are possible based on the stacked-OFDM approach. Thus, several sub-channels are stacked together, requiring only few zero-carriers between themselves. Additionally, this approach is leading to interesting MAC/DLC mechanisms, since several sub-channels can be reserved for one or more users at different instants of time. Moreover, new OFDM modulation schemes are under consideration. State of the art Zero-Padded OFDM [15] is a promising candidate since it grants symbol recovery irrespective of channel nulls. That is to say, it enables the decoding of all OFDM carriers even if certain carriers are deeply attenuated by channel nulls (in absence of noise). Note that more advanced modulation solutions are under investigation yielding an easy semi-blind channel estimation and tracking. Since the impact of Doppler at 60GHz for a given mobility is 12 times higher than in the 5GHz band, blind tracking strategies are desirable for limiting the traditional resulting pilot overhead leading to spectral efficient schemes. Additionally, single-user spread spectrum techniques [16] are under consideration for better channel frequency diversity exploitation (e.g. single carrier with cyclic prefix). Finally, it is intended to define the OFDM symbols such that new low-power architectural approaches are possible. For example, a reduction on the A/D converter requirements is planned while correcting the inherent clipping effects in digital. Another approach is to reduce the memory of the channel encoder, thus maximum likelihood decoding in the receiver becomes far less complex. The loss of frequency diversity may be regained by combining these short encoders with the above mentioned single-user spread-spectrum techniques. These allow various levels of performance/complexity trade-offs in the decoder. Thus, vendors may propose multiple solutions ranging from low cost and medium performance to medium cost and high performance.

Concerning the RF module, the goal is to provide a low cost integrated front-end architecture with dual 5/60GHz frequency operation. For its high integration capabilities, the front-end is modeled/fabricated using integrated QMMIC multi-functional blocks. QMMIC is based on the combination of conventional MMIC using on hybrid HEMPT (High Electron Mobility Pseudomorphic Transistor) technology and Resonant Tunneling Diodes. In order to allow dual frequency operation, 5GHz is considered as an intermediate frequency. This way the 60GHz extension can be plugged to a 5GHz system and consists in a 5-to-60GHz up-converter in the transmitter and a corresponding down-converter combined with a LNA in the receiver as depicted in figure 3. From a technological point of view, though SiGe seems a suitable technology for the 5GHz transceiver, the additional 60GHz front-end will rather aim at the InP technology combined with some external filters. InP offers superior performance in terms of noise, Fmax, power handling, etc. Moreover, together with larger Fmax, a larger feature size is useable making InP processing cheaper than GaAs. It is expected that the packaged price of InP and GaAs will be roughly equivalent in 5 years time for the small feature size.

VI. CONCLUSION

The mission of BROADWAY is to provide a hybrid system solution able to cope with near term user throughput requirements coping for very dense urban deployments while granting a smooth evolution path to current 5GHz OFDM WLAN technologies. BROADWAY consists in a two systems solution bridging the 5 and 60GHz band incorporating innovative concepts on the DLC/RF/Baseband layers. It is expected to be a potential candidate for future WLAN standards.

VII. ACKNOWLEDGEMENT

Note that the BROADWAY project is funded by the IST – Information Society Technologies program of the European Commission (see http://europa.eu.int/information_society).

The authors would like to acknowledge all the partners of the project for their valuable contributions and discussions: These are Motorola Labs France, TNO-FEL Netherlands, INTRACOM and University of Athens Greece, IMST and IRK and Dresden University of Technology Germany, FARRAN Ireland.

REFERENCES

[1] L. Fernandes, "R2067 MBS - Mobile Broadband System", in Proc. of ICUPC'93 - 2 nd IEEE International Conference on Universal Personal Communications, Ottawa, Canada, Oct.1993.

[2] M. Dinis, et al., "SAMBA-a step to bring MBS to people", in Proc. ACTS Mobile Communications Summit'97, Aalborg, Oct.1997, pp. 495-500.

[3] J. Mikkonen, J. Aldis, G. Awater, A. Lunn, and D. Hutchison: „The Magic WAND - Functional Overview“. IEEE Journal on Selected Areas in Communications, Vol. 16, No. 6, Aug.1998, pp. 953-972.

[4] D. Wisely, W. Mohr and J. Urban: „Broadband Radio Access for IP-Based Networks (BRAIN).“ Proceeding IST Mobile Communications Summit 2000, Galway, Ireland, Oct.2000, pp. 89-94.

[5] M.Bronzel, D.Hunold, G.Fettweis, T.Konschak, T.Dölle, V.Brankovic, H.Alikhani, J-P.Ebert, A.festag, F.Fitzek, A.Wolisz, “Integrated Broadband Mobile system (IBMS) featuring wireless ATM“, MobileComm. Summit, 1997, Digest, pp. 641-646.

[6] C.Ciotti and J.Borowski: „The AC006 MEDIAN Project – Overview and State of the Art.“ Proc. of ACTS Mobile Communications Summit 1996, Granada, Spain, Nov.1996, pp. 362-367.

[7] I. Saarinen, M. Lasanen, P. Ruuska, G. Girola, A. Caverni, M. Torregiani, J. L. Garcia, A. G. Armada: „Main approaches for the design of wireless indoor flexible high bit rate WIND-FLEX modem architecture.“ Proceeding of IST Mobile Communications Summit 2000, Galway, Ireland, Oct.2000, pp.51-56.

[8] S. Recker, F. Casadevall, O. Drögehorn, B. Heinrichs, H.Y. Lach, E. Scarrone, O. Schreyer, P. Waldow: „Wireless Internet Architecture and Testbed for WINE GLASS.“ Proceeding of IST Mobile Communications Summit 2000, Galway, Ireland, Oct.2000, pp. 109-114.

[9] „Fibre Radio ATM Network and Services.“ final ACTS research project report, document ref. nr. AC083-SEL-CRC-AR-P-005-b1.

[10] C. Evci, et al, "Emerging Wireless Broadband networks", IEEE Communications Magazine, Feb.1998, pp. 112-117.

[11] A. Finger, W. Nowak, G. Fettweis, R. Lehnert: Breitbandige Übertragung von Multimedia-Daten. 2. ITG-Fachtagung "Multimedia" Dortmund, Sept. 1997, ITG Fachtagungsbericht Nr. 144, VDE-Verlag Berlin Offenbach 1997, S. 21- 30

[12] T. Tjelta, A. Nordbotten, C. Adams, K.H. Craig: „Millimetre broadband radio access optimised to serve the business as well as the residential market: views from the IST Project EMBRACE.“

[13] European Telecommunications Standards Institute core HIPERLAN/2 specifications: ETSI TS 101 475 v.1.1.1, ETSI TS 101 761-1/2/4, ETSI TS 101 493 1/2, ETSI TS 101 763 1/2.

[14] Peter Smulders: Exploiting the 60GHz Band for Local Wireless Multimedia Access: Prospects and Future Directions, IEEE Communications Magazine, January 2002

[15] B. Muquet, M. de Courville, G.B. Giannakis, Z. Wang, and P. Duhamel. Reduced Complexity Equalizers for Zero-Padded OFDM transmissions. In *IEEE International Conference on Acoustics, Speech, and Signal Processing*, Istanbul, Turkey, June 2000

[16] P. Maillé, M. Debbah, P. Loubaton, and M. de Courville. Asymptotic Analysis of Successive versus Parallel Interference Cancellation Schemes for Block Precoded OFDM. In *Proceedings of the Allerton Conference*, 2001.

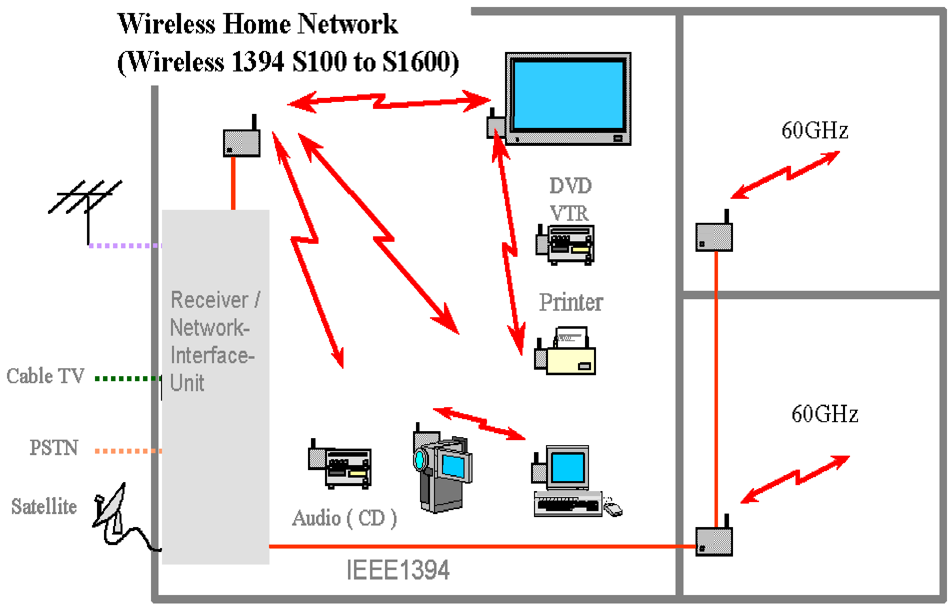

Figure 1: Illustration of BroadWay in the home environment

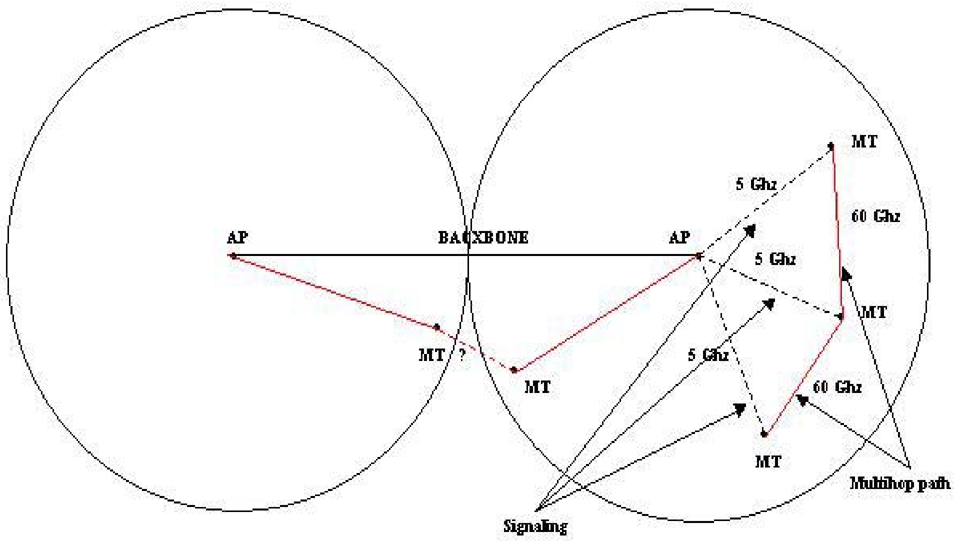

Figure 2: Network topology

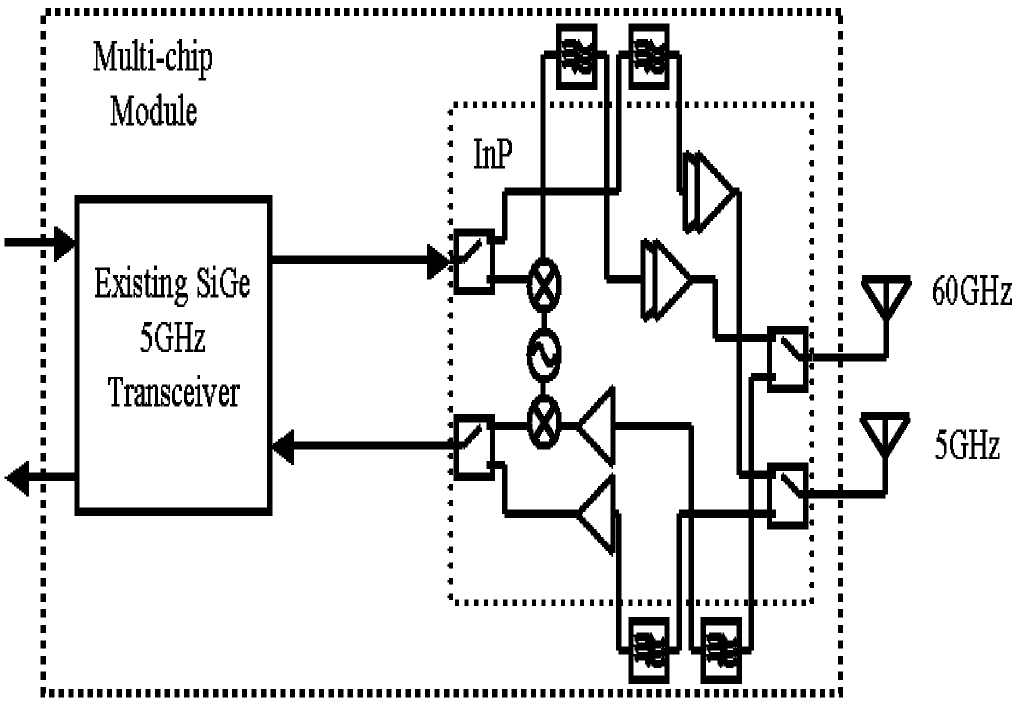

Figure3: Illustration of the dual frequency RF architecture