IST Project: BroadWay - the Way to Broadband Access at 60 GHz

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BroadWay (IST-2001-32686) is an Information Society Technologies project. It is a three-year project, which started in 2002, and it is partly funded by the Commission of the European Community. The partners involved in the project are the Motorola Labs (France), TNO-FEL (Netherlands), Intracom and the National & Kapodistrian University of Athens (Greece), IMST, IRK and Dresden University of Technology (Germany) and FARRAN (Ireland).

BroadWay aims to develop a tightly integrated platform for hot spots supporting private (e-home, entertainment, business) and public (fast outdoor downloading) applications. This platform will be able to cope with very dense user environments satisfying the user expectations in terms of the available throughput. BroadWay objectives include the definition, development and demonstration of the components of a hybrid dual frequency system based on HIPERLAN/2 OFDM high spectrum efficiency technology at 5 GHz and an innovative fully ad-hoc extension at 60 GHz, named HIPERSPOT. The HIPERSPOT system architecture will be based on hardware extensions of HIPERLAN/2 in order to ensure easy reconfigurability and allow for backward compatibility with the 5 GHz technology. It will support two compatible classes of mobile terminals: one of lower cost that will target the same transmission speed as HIPERLAN/2 (25 Mbps or even less data rate) and one providing a significantly higher data rate (more than 100 Mbps) than the maximum possible in HIPERLAN/2 by exploiting the larger bandwidth available at 60 GHz. HIPERSPOT will be equipped with a novel modified multi-carrier transmission scheme enhancing the robustness of transmissions at 60 GHz. Main goals of BroadWay are to offload the 5 GHz radio band in dense deployment areas, to exactly focus radio beams and to allow for self-organizing autonomous operation at the new frequency.

BroadWay is obviously part of the 4G scenario, as it complements the wide area infrastructure by providing a new hybrid air interface technology working at 5 GHz and at 60 GHz. This air interface is expected to be particularly innovative as it addresses the new concept of convergence between wireless local area network and wireless personal area network systems. The concept of BroadWay extends and complements existing 5 GHz broadband WLAN systems into the 60 GHz range allowing for terminal mobility while providing much higher capacity (achieving data rates exceeding 100 Mbps) and increased privacy. For the first time a spectral efficient broadband modulation scheme at 60 GHz will be presented. The tight integration between both types of system (HIPERLAN/2 and HIPERSPOT) into the BroadWay frame will result in a wider acceptance and lower cost for both of them through massive silicon reuse. BroadWay provides a very high data rate mode for wireless broadband services, flexibility in order to adapt to changing environments and traffic requirements, spectral efficiency, efficient support of IP-based backbone networks and services, compatibility with existing communications systems and support of ad-hoc networking. One of the innovative aspects of the system is that it provides a solution to the problem of the inter-cell interference of the 5 GHz wireless networks that are expected to proliferate in the near future due to the expected increase of service demand and user density. This is achieved by proposing a system vision that already integrates current technologies by offering a bridge between the 5 GHz and 60 GHz spectrum. This way, offloading the 5 GHz radio spectrum from data traffic is possible through seamless switching to 60 GHz using the new HIPERSPOT extension of HIPERLAN/2 when in range of coverage.

BroadWay includes innovative work in the physical and baseband layers as well as in the link and convergence layer architecture. Concerning the Radio Frequency module, BroadWay targets the development of a low cost integrated front-end architecture with dual 5/60 GHz frequency operation. For its high integration capabilities, the front-end is modelled using QMMIC (Quantum Monolithic Microwave Integrated Circuit) multi-functional blocks. QMMIC is based on the combination of conventional MMIC (Monolithic Microwave Integrated Circuit) used on hybrid HEMPT (High Electron Mobility Pseudomorphic Transistor) technology and Resonant Tunnelling Diodes. It addresses the problem of 60 GHz smart antenna as well as the coexistence of two such systems in one small antenna. Planar antenna technology is required to develop miniaturized systems for use in both the HIPERLAN/2 system and the HIPERSPOT extension at 60 GHz. Due to the frequencies addressed, the size of the antenna will be small, which allows for the implementation of smart antennas not only in the base stations but also directly in the handheld equipment. According to the project objectives to offload an existing WLAN system (HIPERLAN/2) and extend this system with additional features, an enhancement of HIPERLAN/2 baseband algorithms is required to cope with the extended system requirements for the additional BroadWay modes. Backward compatibility is ensured to reuse HIPERLAN/2 hardware and software building blocks. The algorithm complexity will be kept as low as possible to provide for a potential mass-market solution. Regarding the link and convergence layer architecture, enhancements in HIPERLAN/2 protocol stack are proposed and evaluated to adapt to the BroadWay environment; these enhancements are validated through simulations to allow for a system that concordantly works in both 5 GHz and 60 GHz.

Focusing on the networking part of the conducted work, major challenges imposed by the dual mode of operation are to be addressed. BroadWay introduces two modes of operation: the cellular one at 5 GHz and the ad-hoc one at 60 GHz. At any time instant, one 5 GHz and several 60 GHz channels (based on the channel bandwidth and spacing) can be used inside the HIPERLAN/2 cell. The Access Point operates at 5 GHz and at 60 GHz simultaneously, whereas the mobile terminals can only operate at one frequency band at a time - meaning that they must switch from one mode of operation to the other. First of all, the support of ad-hoc functionality at 60 GHz in BroadWay by incorporating existing ad-hoc algorithms is not effective. Preliminary tests in the 60 GHz band have shown that communication in this frequency is strongly limited due to the Line Of Sight constraint. Although higher speeds can be achieved, the communication range cannot exceed 15-20 meters at most. In addition, indoor or outdoor environments as well as the mobility of users affect the stability of 60 GHz links. Simulations have shown that as the number of hops to reach a destination using the 60 GHz band increases, the lifetime of the path drastically decreases. Due to the short-range nature of the links at 60 GHz, it is inefficient to consider the construction of paths of more than 2-3 hops. Moreover, there are several frequency channels, which a mobile terminal can be tuned at. Thus, the design of a new protocol is needed to cater to the system's complexity and enable the establishment of 5 GHz and 60 GHz links. To support routing in the BroadWay system, it is necessary to determine which nodes operate at which frequency band as well as to establish efficient routes at 60 GHz. Since distributed routing protocols used for pure ad-hoc networks are not applicable in the BroadWay environment due to short-living 60 GHz links, QoS demands and system's peculiarities, a centralized routing scheme is considered where the Access Point is responsible for making routing decisions at both frequencies and allocating the needed resources, based on information collected during the neighborhood discovery process. This process provides the AP with 60 GHz topology information (every mobile terminal's one-hop away neighborhood and the quality of the corresponding links when operating at 60 GHz). Since the 60 GHz links may typically last for only a few seconds, the information collected by the neighborhood discovery process needs to be refreshed frequently. This would require an additional overhead that should not deteriorate the performance of the overall system, but contribute to offloading the 5 GHz band by enabling the establishment of credible 60 GHz paths. Among the critical issues that affect the performance of BroadWay is the switching time required not only for changing band (5/60 GHz) but also for switching between the various 60 GHz channels, the scheduling of transmissions inside the HIPERLAN/2 cell, the synchronization between the frames at 5 GHz and 60 GHz, and the signaling burden to incorporate the ad-hoc functionality at 60 GHz. The format of the HIPERLAN/2 frame needs to be enhanced to cater to the system's functionalities and a new frame at 60 GHz needs to be defined to enable the communication at the new frequency.