Results Paper

Information Society

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Broadband Air Interface Cluster

BAI - Broadband Air Interface cluster

BAI cluster gathers FP6 IST projects dealing with radio layers. At this level, ambitious goals in terms of high bit rates wireless communications involved joint research in communication theory, information theory, signal processing, propagation, antennas and real-time hardware. The BAI cluster provided a forum for interdisciplinary confrontation.

FP6 BAI Cluster

1) STATE OF THE ART AT THE END OF FP5

At the end of FP5, the issue of a new air interface for Beyond 3G systems was still open, with targeted bandwidths up to 100 MHz and spectral efficiency up to 10 bit/s/Hz. Modulation scheme had first to be chosen. The trend towards multi carrier modulation was present at the end of FP5, but no choice had been made yet. Research on various spectrum efficiency enhancement tools, such as multiple antennas and relays, was on going. Single user Multiple Input Mutiple Output (MIMO) schemes were already widely studied, though receiver complexity seemed still an issue. Multi-user MIMO schemes studies had just started. Relay benefits in terms of coverage extension had been acknowledged, but cooperative relaying, as well as ad hoc and routing, only started to be considered in the context of cellular or fixed wireless access networks. On the other hand, topics such as Personal Area Networks (PAN) were still in their infancy. Ultra-Wideband (UWB) European research had not yet been integrated in a global approach. Appropriate channel models for all these cases were not completely available yet. These topics had been considered in FP5 projects: MATRICE, i-METRA, STRIKE, STINGRAY, BROADWAY, FITNESS, UCAN, ROMANTIK, ULTRAWAVES.

2) WHAT WERE THE CLUSTER OBJECTIVES AND VISION?

One of the goals of FP6 IST projects, regarding Mobile and Wireless Systems Beyond 3G, was to reach a consolidated European approach to technology, in the field of future standards. In this context, the objective of the BAI cluster was to provide a forum for IST projects dealing with wireless high bit rates, at the radio layers level. The UWB cluster from FP5, merged with BAI in FP6. A subsidiary goal was to create opportunities of bilateral cooperation between projects, whenever appropriate. BAI cluster has met on regular basis in Brussels and during IST Summits, with participation from projects 4MORE, MASCOT, UNITE, WINDECT, WINNER I and II, FIREWORKS, MAGNET, PULSERS, NEWCOM, ACE, URANUS, WIDENS, OBAN, E2RII, MEMBRANE, and SURFACE. Also, several workshops have been organised, with external experts (on system level methodology, and on cognitive radio, together with SRM cluster).

FP6 BAI cluster Achievements

1) Cluster Achievements

FP6 BAI cluster targeted information exchange on spectrally efficient and cost effective B3G and PANs air interfaces. Significant advances in connected areas such as channel models, algorithms and real-time devices were obtained. Pioneering results have been obtained during FP6, in terms of

Propagation Channel models

- Relaying requires specific channel models, relay to relay, mobile to relay. FIREWORKS and WINNER built on ROMANTIK (FP5) pioneering results.
- Wideband communications also involve appropriate channel models, with both spatial and temporal characteristics. WINNER built such models, used also as input for IEEE802.16m, 3GPP LTE, WiMAX... standardization organisations. WINNER They have also been contributed to ITU-R WG 8F, and are a serious candidate for the basis of IMT-Advanced channel models. In addition, they are used by SURFACE, MEMBRANE (with some modifications in order to address the wireless backhaul scenario)

Algorithmic work

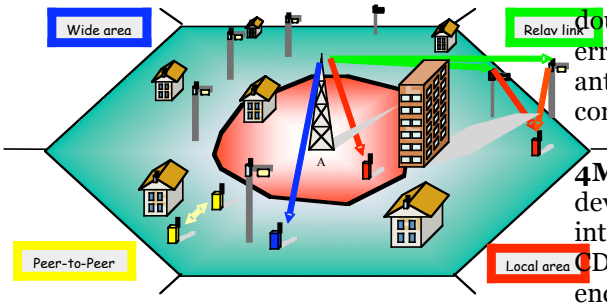
- Advanced Multi user MIMO schemes have been introduced by WINNER, MASCOT and SURFACE.
- Progress on relay concept was made by both WINNER I and II and FIREWORKS. Both projects considered cooperative relaying, which may be viewed as a “virtual” MIMO scheme.
- Advanced techniques that combine relaying and MIMO approaches have been developed in MEMBRANE

Proof-of-concept real-time hardware demonstrators

- Demonstrators have been (or are currently) built by 4MORE, WINNER II, MASCOT, PULSERS Phase II, URANUS, FIREWORKS and MAGNET.

A consolidated approach in terms of enabling technologies for future highly spectrally efficient air interfaces spanned all cluster projects. MIMO technologies, virtual MIMO

(relay), appropriate channel models, efficient coding schemes and advanced System on Chips (Network on Chips) were at the heart of studied areas. These results are reflected in a large number of publications, and of contributions to standardisation.



It should also be noted that several bilateral project cooperation occurred, e.g. between WINNER and 4MORE, between SURFACE and MASCOT (joint SURFACE-MASCOT Multi-user MIMO Communications tutorial) and between ACE and NEWCOM (a joint Smart Antenna workshop in 2005 and a joint Special Session at PIMRC 2005). Also, some projects fostered cooperation between partners, beyond the project framework.

2) Outstanding Project Contribution

Channel models

WINNER developed a generic model, covering 12 mobile and 5 fixed propagation environments. The models are applicable over the frequency range of 2 to 6 GHz and their RF band-width is 100 MHz. In similar conditions the complexity of this modelling approach is comparable or even smaller than for the alternative modelling methods**.**

PULSERS project members contributed to IEEE 802.15.4a channel models.

MAGNET developed novel channel models for both wideband (at 2.4 and 5.2 GHz) and UWB (at 3-5, 17 and 60 GHz) systems, which incorporate the main PAN characteristics: user dynamics and device handling, body area and body-proximity effects, peer-to-peer communications scenarios. At 3-5 GHz, different configurations of multi-antenna structures were tested in order to highlight its role in UWB MIMO system.

Algorithmic work

OBAN modified the classical beam forming algorithm taking into account equivalent isotropic radiated power (EIRP) constraint. A significant range (coverage) extension gain was obtained compared to the single-antenna access point (AP), e.g. average (2-4)-times gain for the 4-antenna AP WLAN. OBAN also proposed an alternating time-offset spatial division multiple access (SDMA) solution, which supports legacy IEEE 802.11a/g terminals and requires some modifications to the transmission protocol at the AP. It has been shown that the downlink capacity in a conference room environment can be almost doubled for low levels of channel reciprocity errors at the AP equipped with three or four antennas depending on the propagation conditions.

4MORE (follow-up of FP5 MATRICE) has developed a complete and consistent air interface definition, based on multi carrier CDMA, that is suitable for 4G transmission. It encompasses physical parameters, complete baseband functional chain for both 2x2 and 4x2 MIMO configurations, together with the definitions of temporal frames. Finally, elements of a MAC protocol solution have been developed. This solution is close enough from the current emerging standards (e.g. 3GPP LTE) to be considered as a reference for 4G OFDMA solution

FIREWORKS is developing multiple transmit and receive antennas physical layer algorithms for relay and cooperative systems. Some of the major techniques investigated are space-time block codes (STBC), Golden Codes, Multi-User Precoding and Detection. Relaying and cooperative schemes at the physical layer are also considered with particular focus to Amplify and Forward /Decode and Forward distributed STBC, Compress and Forward techniques and selective relaying. FIREWORKS work extends the achievements of FP5 STRIKE, STINGRAY and ROMANTIK.

URANUS goal is to propose a reconfigurable architecture for various standards (UMTS, WiMAX, 802.11x, GSM…), based on the concept of Generalised Multi-Carrier (GMC) signals. A novel receiver architecture was proposed, capable of processing both single and multi-carrier baseband signals under a common FFT module, using the concept of Gabor frames. It relies on the one-tap channel model assumption, which was validated for WCDMA downlink transmission. An appropriate channel estimation scheme has been developed. Issues of peak-to-average power ratio reduction have been considered. A novel initial synchronisation algorithm based on GMC was developed.

MEMBRANE investigates reconfigurable antenna techniques for wireless backhauling applicable to a wide range of system configurations. In MEMBRANE a data splitting algorithm for MIMO relay systems has been developed. The algorithm exploits

the propagation characteristics of the relay links to optimally split the transmission data stream to several sub-streams forwarded to the final destination. Algorithms for a two-path relaying protocol have been developed and a selection criterion between these algorithms was deduced. An interference cancellation algorithm at the receiver side using multiple antennas was also proposed.

UNITE An optimal decoding and power allocation for SIC, MMSE and matched filters was derived, using asymptotic tools from random matrix theory. Power allocation is thus performed in a decentralised manner.

WINDECT used IEEE 802.11e with a minor modification to achieve seamless hand-over from access point to access point, and, with voice processing, to achieve greatly improved bit-error control. New approaches to minimising power consumption were proposed, making WINDECT devices broadly equivalent to traditional DECT.

SURFACE addressed the optimisation of linear MIMO transceivers under a minimum BER criterion. In order to tackle the limitations arising from the common practice of a priori fixing the number of symbols to be transmitted, a multimode procedure was developed that adaptively selects the optimum number of modes for a given target rate. The proposed multimode minimum BER design achieves the full diversity of the channel in both the perfect and partial channel state information scenarios.

The goal of **WINNER** is to develop a single ubiquitous radio access system adaptable to a comprehensive range of mobile communication scenarios from short range to wide area. This is based on a single radio access technology for the PHY and MAC-layer A toolbox of components has been developed to enable such an adaptive system.

NEWCOM activities in this topic focused on the design of highly power and bandwidth efficient, flexible coding and modulation schemes. A serially-concatenated code has been designed and tested, allowing to reach a performance at 1 dB from channel capacity over a wide range of spectral efficiencies, from 0.66 to 5.2 bit/s/Hz**.**

ACE is developing multiple antenna techniques for cooperative communications distributed schemes aiming to exploit spatial diversity, multi-user MIMO cross layer designs, including multi-dimensional packet scheduling and a framework and methodology for context-aware optimisation with Smart Antennas.

MAGNET and **MAGNET Beyond** developed and optimised WPAN specific air interfaces: two physical (PHY) layers were developed, a high-data rate (HDR) MC-SS PHY layer and a low data rate (LDR) FM-UWB PHY layer. In addition, measurements proved significant power level gains for a simple switched diversity system in a handheld to handheld scenario. Also interference to the HDR mode from other systems was modelled and mitigation mechanisms were introduced, such as power loading, interleaving and space diversity (MIMO) techniques.

Proof of concept HW demonstrators

4MORE platform consists of a Mobile Terminal (MT platform) demonstrator on one side, combined with a dedicated Base Station emulator on the other side. A MIMO 2x2 scheme was implemented. Original components have been designed: the radio stages with their dedicated antennas, the specific RF front-end, a baseband modem based on an innovative and flexible architecture on SoC and finally, a simplified MAC software component.

WINNER demonstrator has been presented the first time at the WWRF-meeting mid of June 2007 in Helsinki.

E2R II platform is a Mobile Terminal (MT) demonstrator. Based on a reconfigurable RF board and a BB board, it aims at prototyping air interfaces for Software Defined and Cognitive Radio. A dynamically reconfigurable SoC has been designed for performance purpose at the baseband side. Advanced functions, such as flexible Low Density Parity Codes (LDPC) or complex MIMO decoding can be programmed on this platform.

FIREWORKS: A real-time channel emulation and cooperative prototype system based on IEEE 802.16 specifications is planned for implementation.

MASCOT is implementing a soft-output sphere decoder in ASIC. One key result is a VHDL library of reference designs for ASIC implementation of MIMO transceivers, notably tailored to IEEE 802.11a/n. This will enable quick commercialisation of the advanced MIMO WLAN algorithms.

PULSERS Phase II: Two demonstrations have been shown recently at the 16th IST Mobile and Wireless Communications Summit 2007 in Budapest. The first one was showing LDR-LT (low data rates with location tracking; PHY + MAC with LT) while the second one was demonstrating HDR (high data rates; Wireless HDMI).

The **URANUS** demonstrator will validate experimentally the generalised multi-carrier concept. A UMTS WCDMA downlink and WiMAX OFDM downlink with the GMC receiver will be demonstrated.

MAGNET and **MAGNET Beyond** developed and implemented a low-band IC and a high-band RF IC for the FM-UWB air interface (VCO, prescaler, WideBand DeModulator (WBDM), LNA, subcarrier processor, DDS). Further, the projects designed and implemented an RF board for the low band system that uses the MAGNET chipset and that is interfaced to the LDR digital board.

MEMBRANE A novel PHY algorithm and a selected MAC protocol will be implemented in a high performance hardware platform. The prototype is composed of 3 nodes and upgrades IEEE 802.16e specifications with MEMBRANE's novel algorithms.

WINDECT demonstrator allowed the high quality and low delay of DECT telephony to be achieved in a 'voice over wireless LAN' representing a converged enterprise network. This was possibly the first use of the new IEEE 802.11e WLAN standard for a 'quality of service' application with the HCCA contention-free MAC, obtaining close to DECT quality, which would not have been achievable with end-to end VoIP.

Current and Upcoming Expected Impact

In summary, both 4MORE and WINNER paved the way for a B3G mobile communication system, based on multicarrier transmission. MAGNET and MAGNET Beyond developed and optimised WPAN specific air interfaces to include the requirements of a highly dynamic PAN. By assembling a critical mass of European key players, PULSERS was able to develop advanced systems and usage concepts, provided technical support to European regulation fora (RS-COM, CEPT) enabling coexistence studies and in this way promoted the use of UWB.

Impacts on standards

Based on the LDPC codes developed and implemented in **4MORE**, a new low complex code class named Ultra-Sparse (U-S-)-LDPC codes have been defined. This code class is now being proposed as an enhanced channel coding scheme for the updated version of the UWB standard in WIMEDIA.

FIREWORKS has presented 2 contributions to the 2nd technical call for contributions the IEEE 802.16j relay task group**.**

WINDECT an extension to the DECT standard had been proposed allowing DECT to be used with an IEEE 802.11 WLAN PHY layer.

PULSERS Phase II members were involved in the definition of both IEEE 802.15.4a and ECMA 368/369. Within ETSI the project actively contributed to TG31a and TG31c.

MAGNET Beyond achievements will forward standardisation in the 802.14 and.15 and also within the ETSI activities. Further, the projects proposed and developed a modified version of the AWMA (Alternating Wireless Medium Access) algorithm for the coexistence of IEEE 802.15.3 and IEEE 802.15.4 air interfaces and a modified version of the PTA (Packet Traffic Arbitration) algorithm for the coexistence of IEEE 802.15.3 and IEEE 802.15.4 air interfaces.

Strong influence from **WINNER** is visible from the intensive contributions towards the definitions of the requirements for IMT-Advanced, currently been established in ITU-R. The concept work produces more and more results by system simulations, which verify the assumptions made in basic technology application as well as in system implementation. Several functionalities are already basis for contributions to 3GPP LTE (WINNER channel model, MIMO, coding).

Dissemination

NEWCOM has held a very successful Dissemination Day in Paris on February 15, 2007. During the event, the main results have been presented to major European Telecom Industries, including demonstrators and software tools developed during the 3 years of network activity.

With the consolidated view of European partners in WINNER, several contacts have been established to other areas in the world, especially in Asia.

Next Steps

WRC 2007 will potentially trigger further technical work in the area of spectrum usage, flexible spectrum assignment and spectrum sharing. It will also impact the definition of an IMT-Advanced technical proposal.

The topics investigated during FP6 BAI cluster, will be further refined during FP7 projects.