Physical Layer Strategies and Issues for ABC Vision

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The next generation wireless (NextG) communication contemplates the integration of all wireless/mobile systems, which means that considerable effort is needed to improve and to introduce design modifications design in the actual communication layers of these engines. From the point of view of research and application, the reconfigurability and adaptability will be an essential part of NextG systems, since it will be the means to achieve the interoperability between the different technologies [1].

Recently, there has been a wide interest in the idea of Cross-Layer[1] (CL) design in wireless networks [1,2,3,4]. This emerging idea has been motivated by the need to introduce major degrees of adaptability and efficiency to variations of the actual communication systems, and thus to take a step forward the challenges of adaptability/reconfigurability and the Always Best Connected (ABC) concepts required for the NextG systems [1]. We define the ABC as a system capability of ensuring that users can always be connected on the best way. Therefore, this means;

- To achieve full interoperability between the different communication technologies (GSM, UMTS, WLAN, Ad-hoc networks, etc...).
- To use adaptable and reconfigurable PHY supports (resources) for each environment change as Channel trafic, application, etc.
- To use the best power saving mode.

Reconfiguration of any part of the communication layer is necessary for the network to have some intelligence and reconfiguration control. A Global Intelligent Reconfiguration Control (GIRC) module is needed to manage each time the different environment variability, such as the user environment, network environment, and radio environment. Here, intelligence is to decide what part or parts of the network should be reconfigured, based on the relevant information supplied to it, and then get the reconfiguration controller to implement these decisions on the appropriate way in the hardware and/or software modules.

Currently, the medium access control (MAC) is designed with a minimum input from the physical layer, where most conventional random access protocols assume that the channel is noiseless and the failure of the reception is caused by collision among users, packets transmitted at the same time are destroyed and retransmission must be made later. In order to face-off the collision resolution problem, the standard design of the MAC is, in general, based either on random access mechanisms (ALOHA, CSMA, and similar) or upon two essential protocol phases that are; **the PHY layer estimation number of the requested channels** and the MAC sub-layer **acknowledgment** that depends upon the PHY output. Typically, most conventional schemes are based on a single channel transmission mode, at the detector the physical layer tests the hypothesis that there is only one request access (or packet), if somehow collision occurs all the packets should be rejected. Therefore, there is no way to extract minimum information from the rejected packets when a collision is detected. Research and developments in PHY-MAC dialogue with multi-packet reception (MPR) that exploit transmission and reception diversity (mainly CDMA and/or SDMA) offers potential improving in the network performance in terms of throughput and delay [4].

[1] *G*IRAFA -Spanish project, under the contract TIC2002-04594-C02-02

In recent years, it has become more and more evident that elements as smart antennas, multiple input multiple output elements (MIMO) and scalable detections will play an important role in modern wireless systems and they will be the main physical layer support resources for achieving the Always Best Connected strategy in the NextG communication systems.
Smart antenna reconfigurability must be implemented by algorithms that implement adaptive channel and bandwidth allocation and power control. However, multiple antennas can offer substantial spectrum efficiency and link capacity. Transmit and receive algorithms as single detection (SD), multi-user detection (MUD) or scalable detections are also very important for the ABC since the performance (of the Tx/Rx schemes) can varying if we adopt a specific algorithm [2, 3].

The cross-layer approach aims at introducing some degrees of knowledge, introducing optimization between the physical and link layer and taking into account both PHY and MAC layers. This design is in its beginning and encompassing the above physical resources is critical as the choice of appropriate and skill parameters that could serve as agents for carrying the information between the communication levels with parameters permitting reconfigurability and achieving the ABC requests. We can classify the exchanged information in the cross-layer as the following;

- **Channel State Information** (CSI) (i.e. estimate the channel impulse response, location information, signal strength, interference level etc.)
- **Physical layer resources** (i.e. number of antennas, spatial processing, etc.)
- **QoS** (i.e. throughput, delay, PER measurement, BER, etc.)

Current researches in reconfigurability involves the use of traditional signal processing methods or classical medium access protocols, and also the deployment of fuzzy logic techniques.
Despite its recent application to communication networks, fuzzy logic techniques are powerful mathematical tools to assign available resources to the several users in a wideband communication. The uniquely analytical modelling of this kind of networks is very difficult not only due to their high complexity but also to the uncertain definition of the parameters describing them. Fuzzy techniques are not based on statistic approaches but on fuzzy sets that allow describing a range of values more flexible than in the traditional signal processing approach. For instance a signal power can be characterised by tow values as “weak” or “strong ” depending on the defined “hard threshold”. However in fuzzy logics the power signal can be characterised using “soft” thresholds that can account some kind of uncertainty (i.e. strong and weak simultaneously). Research works developed in [3] give us clear idea of reconfigurability, combining multiple antennas for increasing the access users at the receivers and fuzzy logics for reconfigure the number of channel taps in accordance with the channel variability of each user.

To develop a cross-layer design, some assistance could be given in determining the most efficient adaptation mechanism (i. e. changing the coding parameter, the transmission rate, power , etc.). At the same time, cross-layer design is confronted with critical issues such the additional signalling needed in order to extract more relevant information for reconfigurability and how to reserve additional logical channels for transmitting cross-layer information to the remote nodes.

References

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