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Radio Resource Adaptive Adjustment in Future Wireless Systems Based on Application Demands

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Abstract:
In wireless communication systems the resource management needs to integrate adaptive techniques to the varying network conditions, due to the eventual dramatic changes that may occur in the link quality. Therefore, it may be desirable to support adaptable resource management techniques that are able to find their decisions in the network configuration information or in the source application description. Accordingly, the paper identifies, explores and proposes adaptive techniques for resource management so as to enhance the transmission quality on wireless systems either through a feedback channel or by making use of the network virtualization concept. Setting up dependencies between the application requests and the radio channel conditions, a feedback loop adaptively configures modulation and coding schemes, calibrates multi-antenna system, controls power per beam allocation or invokes a linear precoding. Finally, when the application requests exceed the network capacity, by the network virtualization process the adaptive potential of the application parameters can be employed, either through source fragmentation or source code adaptation.
Keywords: Resource management, adaptive techniques, feedback loop, network virtualization.

1 Introduction

Since the radio resources are limited and the demand for more and more complex wireless services is increasing, adaptive techniques are considered as powerful means for improving the link performance of future wireless networks [1]. The proper delivery of a certain application is usually conditioned by a set of source application's requested parameters, for which some minimum requirements are imposed. By providing an adaptive controlling of the system resources, both from the network's and application's perspective, a better radio resource management can be achieved, as well as an improved transmission quality adapted to the varying channel conditions.

The goal of the paper is to analyze and highlight the adaptive potential of different techniques: either at the physical layer (PHY), based on a feedback loop, or at the application layer (APP), based on network virtualization. A similar approach can also be found in [2], where the effect of some parameters such as: number of transmitting nodes, packet length, modulation scheme and mobile nodes speed was investigated. If in [2] the improvements obtained by applying each of these adaptive techniques were viewed separately, only at a block level, the current paper goes beyond, and targets to a more unified approach by analyzing the impact of applying these techniques at a system level. Also, this idea of adaptability, started in [2], is continued with the most recent in use standards and concepts, IEEE 802.16e Wireless Metropolitan Area Networks (WMAN), IEEE 802.11n Wireless Local Area Networks (WLAN) and the network virtualization process. Other adaptive techniques approaches, at block level, were developed in [3] where it is shown that, in order to meet the performance requirements, the employed modulation and coding schemes vary with the channel conditions. Also, an antenna management algorithm is presented in [4]; it can adaptively disable some of the employed antennas of the system so to meet the capacity and the energy per bit constraints. In [5], spatial diversity is considered as means to enhance the throughput of the WLAN physical layer, under different channel conditions, without the transmitter being aware of the channel variation. Thus, by an adaptive controlling of the network configuration parameters or by an adaptive adjusting of the application transmission parameters, a more efficient use of the available resources can be obtained in order to better satisfy the application requested parameters.

The conducted analyses, developed around this concept of dynamic network awareness and dynamic control of the available radio resources, based on the received feedback information, will be extremely important for the development of future wireless systems characterized by high data rate services having strictly quality of service (QoS) demands [6]. In order to demonstrate that, the paper is organized in seven sections, as follows: after a short introduction presented in Section 1, Section 2 focuses on the identification and grouping of these adaptive techniques into two main categories, indicating also their adaptive potential. By making use of an adaptive technique at the network configuration level, the transmission performances can be greatly increased. Section 3 aims to evaluate the network's adaptive potential, at the transmitter side, mainly with respect to the adaptive modulation and coding (AMC) schemes that can be employed. By implementing such a mechanism, significant improvements of the system's performance can be obtained. In Section 4, the air interface reconfiguration is proposed, due to the channel capacity dependency on the number of active antennas as well as on the propagation channel state. In Section 5, we evaluate the adaptive potential of spatial transmit processing techniques, when a precoder is used to optimize pertinent criteria. When due to operational costs or technical constrains the adaptability level with respect to the network configuration parameters is limited, the application's transmission parameters must be adjusted. Section 6 illustrates the adaptive potential at the application level, by making use of network virtualization. Finally, the conclusions are drawn in Section 7.

2 Adaptive Techniques in a Wireless System: Identification and Potential

The paper identifies and further evaluates the adaptive potential of some techniques that can be used for resource management in wireless systems. The paper groups these adaptive techniques in two major categories, as follows: (1) PHY adaptive techniques, based on a feedback loop: modulation and coding schemes, multi-antennas system configuration, optimal power allocation and linear precoding, and (2) APP adaptive techniques, based on network virtualization: application layer source packet size or number of transmitted packets.

The adaptive solutions synthesized in Figure 1a illustrate the adaptive potential of different transmitter (Tx) / receiver (Rx) blocks. These techniques need or include a feedback reaction from the physical network level. By using different configuration techniques on the Tx / Rx blocks, the available network resources can be efficiently adapted to the imposed source application requested parameters.

Some critical conditions or cost constrains could limit the network's resource optimization level. These situations impose the adaptation of the source application parameters to the network available resources. In order to indicate the adaptive potential, but in a strict parametric control way, at the application level, the paper introduces the concept of network virtualization. Network virtualization is a technique that consists in clustering logical resources into virtual networks from the physical network infrastructure. The objective of this virtualization process is to make each virtual network appear to the user as a dedicated network infrastructure, with dedicated resources and services available for application requests. Therefore, the adaptive potential of the application parameters network virtualization, presented in Figure 1b, invokes a model of selecting the virtual network that best integrates and satisfies the application requests at the physical network level.

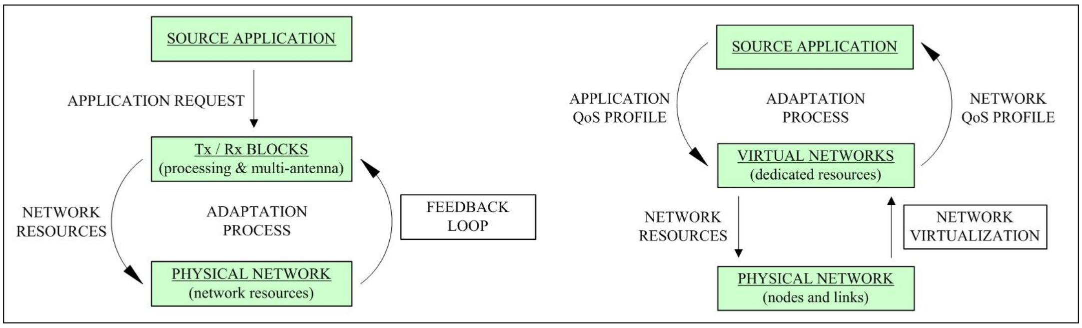

Figure 1: (a) Adaptive resource management techniques through a feedback loop (left), and (b) Adaptive resource management techniques based on the network virtualization process (right).

Thus, in the next Sections of this paper, different resource management techniques are evaluated both at the network and application level, by highlighting their adaptive potential.

3 Adaptive Potential of Transmitter Modulation and Coding Schemes

Link adaptation techniques rely on the dynamic configuration of certain transmission parameters such as the modulation and coding scheme, according to the variable channel conditions, given some constraints imposed by the communication system. These constraints can be expressed in terms of a target bit error rate (BER) and throughput. Several mechanisms can be employed to maximize the throughput in a time varying channel, but all of these involve the presence of feedback between the transmission and the reception. Feedback is critical especially when we refer to adaptive modulation and coding (AMC). In this case, for an efficient management of the available resources, the transmitter needs to be able to anticipate the channel's variations and adapt accordingly to it. In Figure 2 this link adaptation mechanism is illustrated, as well as the parameters taken into account.

The benefits that result from applying a link adaptation technique, in this case AMC, will be illustrated for the case of a wireless metropolitan area system (IEEE 802.16e). The WirelessMAN-OFDMA (Orthogonal Frequency Division Multiple Access), basic radio interface both for portable and mobile applications, has been selected for the performed simulations [7].

System Parameters: The main values for the system parameters are presented in Table 1, and are set in accordance to the recommendations from [7] and [8], such as to build a realistic system. A downlink transmission was considered, from the BS (Base Station) transmitter to the MS (Mobile Station) receiver.

The radio channel plays a key role in the link adaptation process, with respect to the evaluation of the transmitter's parameters. One of the most used set of channel models for the simulation of different types of environments affected by frequency-selective fading is the ITU-R set of channel models [8]. The parameters characterizing the Ped.B channel model, which is used for modeling indoor to outdoor pedestrian single input single output (SISO) environments can

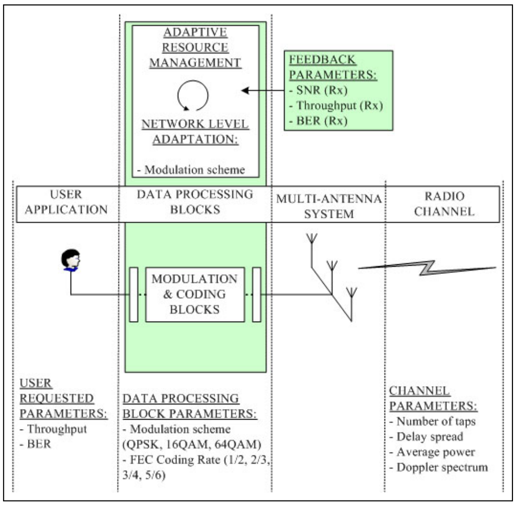

Figure 2: AMC parameters and feedback information.

Parameter	Value
Carrier frequency (GHz)	2.3
Channel bandwidth (MHz)	10
Transmitter power (dBm)	20
BS antenna gain (dBi)	15
MS antenna gain (dBi)	0
FFT size	1024
Subcarrier allocation mode	DL PUSC
Duplexing scheme	TDD
Velocity of the MS (km/h)	3
Distance between BS and MS (km)	0.1

Table 1: System parameters.

be found in [8]. In this case the channel profile is determined by the number of multipath taps that reach the receiver, and the relative delay and average power associated with each individual multipath component. Such a channel can be considered as a good representative of an urban macro-cellular environment.

System Requirements: As expressed in [9] for most applications (especially multimedia) a BER less than 10^{-6} is required. Also, for being able to satisfy even the most bandwidth consuming applications, we impose a minimum of 1Mbps link throughput even under a worst case scenario.

System Analysis: The BER performance for various modulation schemes as a function of the received SNR (Signal-to-Noise Ratio) is presented in Figure 3, for the case of a convolutional turbo coding (CTC) scheme. Such a coding scheme is recommended to be used especially when referring to wireless applications on anticipated non line-of-sight environments. In this way, it is possible to counteract the unwanted effects which might appear due to the different delays of the multipath components which may lead to inter-symbol interference (ISI) [10].

A certain imposed QoS level, in 802.16 systems, from a PHY perspective can be assured by making use of adaptive modulation and variable FEC (Forward Error Correction) coding. Such a technique, known under the name of adaptive modulation and coding (AMC) can be applied on a sub-carrier basis, according to the random fluctuations of the radio channel [3] [11]. In this case, different spectrally efficient modes (where a mode is defined as a combination of modulation

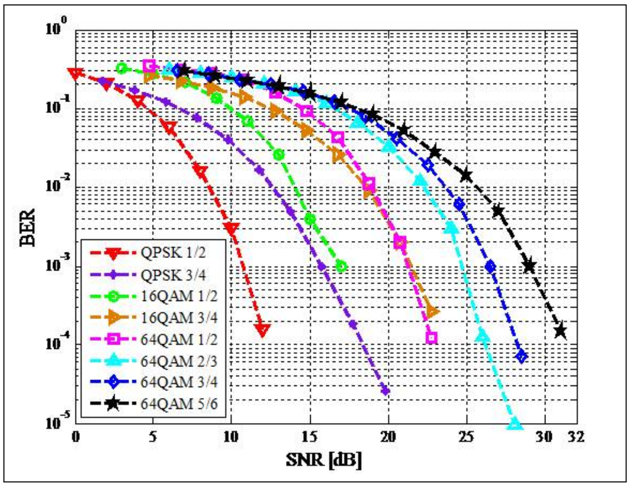

Figure 3: BER versus SNR system performance.

and FEC coding rate) can be alternated for increasing the throughput, assuming that the signal-to-noise (SNR) thresholds required for passing from one mode to another are available at the transmitter. In applying AMC, feedback information related to the current state of the radio channel is needed. The MS can feed back channel state information (CSI), that can be used by the BS scheduler to assign a modulation and coding scheme that maximizes the throughput for the available SNR, using for this the Channel Quality Indicator CHannel (CQICH) included in the TDD uplink subframe.

In Figure 4a, the link throughput versus SNR envelope is presented, taking into account the application error requirements imposed above (BER $<10^{-6}$). For high SNR values the highest order throughput scheme will be selected (64QAM 5/6) in order to efficiently use the channel's capacity. During deep fades when the quality of the radio channel degrades rapidly in time, a lower order throughput scheme will be employed (QPSK 1/2) in order to avoid an excessive number of dropped packets as well as to avoid losing the connection quality and link stability.

A similar envelope generated using AMC, to increase or decrease the link speed depending on the received SNR, but this time with respect to the maximum operating distance, is presented in Figure 4b. The maximum operating distance that can be reached by using a certain link speed was derived from the path loss equation for indoor to outdoor pedestrian environments expressed in [8] and the link budget equation expressed in [3].

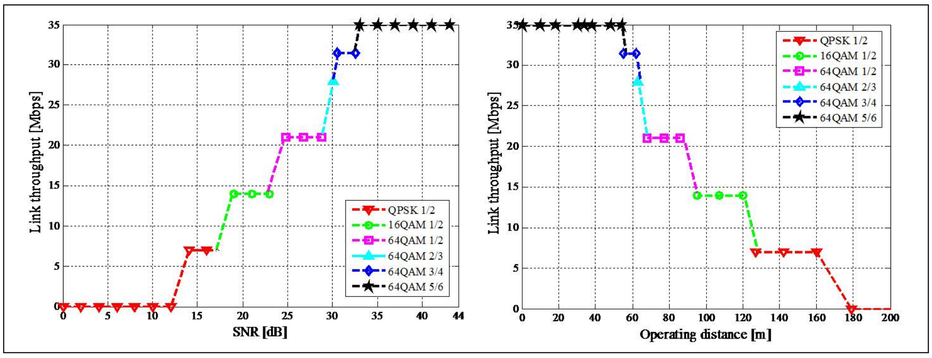

Figure 4: Ped.B channel model: (a) Total achievable link throughput (left). (b) Maximum operating range (right).

Based on the application constraints and on the fact that each mode needs a certain robustness level in order to be activated (a minimum SNR value) we conclude that each mode is optimal to be used in a different channel quality region. An example of a lookup table at the transmitter, where both the SNR domain and the maximum operating range for each of the possible modes that can be employed, is presented in Table 2.

Source application requested parameters: BER $< 10^{-6}$, Data Rate $\geqslant$ 1 Mbps		
SNR (dB)	**Operating range (m)**	**Modulation and coding scheme (MCS)**
12.1 - 17	178 - 127	QPSK 1/2
-	-	QPSK 3/4
17 - 24	127 - 95	16QAM 1/2
-		16QAM 3/4
24 - 29.1	95 - 68	64QAM 1/2
29.1 - 30.1	68 - 62	64QAM 2/3
30.1 - 32.9	62 - 55	64QAM 3/4
$>$ 32.9	$<$ 55	64QAM 5/6

Table 2: Transmitter lookup table for the case of the Ped.B channel model.

If the channel's variations are sufficiently slow and the channel quality information (received SNR) can be fed back to the transmitter, then by making use of the AMC technique an optimum use of the available radio resources is obtained. Still, in applying such a technique a cross layer interaction between the PHY and APP layers must exist, as the system needs to know about the application's QoS requirements as well as the received SNR in order to be able to determine the appropriate switching point and link speed for the current flow [6].

4 Adaptive Potential of Multi-Antennas System Configuration

The main idea of this section is to explain the need for an adaptive configuration of a Uniform Linear Array - Multiple Input Multiple Output (ULA - MIMO) system in what concerns the number of active antenna elements used at the transmitter and receiver, when the inter-element distance is constant. The basic criteria which dictate the system reconfiguration are the channel status, the changeability of the propagation environments, conjunctively with the constraints related to the channel capacity in bps/Hz needed to support the transmission of the required amount of information. Figure 5 depicts the channel and the air interface parameters that are taken into account when performing the adaptability of multi antenna system configuration.

System Parameters: The MIMO air interface is characterized by the number of antenna elements used at both transmitter and receiver side and by the inter - element distance, given in wavelength, λ. We consider a $4\times$ 4 uniform linear transceiver with an inter- element distance of 0.5λ. At this value, the correlation degree at both ends of the communication link provides a low diversity order which characterizes the real propagation environments [12]. In this paragraph we use a uniform power allocation scheme and a variable number of simultaneous active antennas. The channel matrix that describes the behaviour of the propagation environment was modeled for a frequency- flat channel, affected by Rayleigh fading. The matrix was derived by integrating the influence of spatial correlation between the transmitted and received signals. The correlation matrices are dependent on the PDP (Power Delay Profile), the physical ray propagation parameters described in [13] like: AOA/ AOD (Angle of Arrival/ Angle of Departure), number of clusters, PAS (Power Azimuth Spectrum), but more strongly on AS (Angle Spread) and on the inter-element distance [14] and [15].

In this paper, two channel matrices are built in order to model environments like residential/small offices (channel C) and large indoor spaces (channel F). The former is characterized

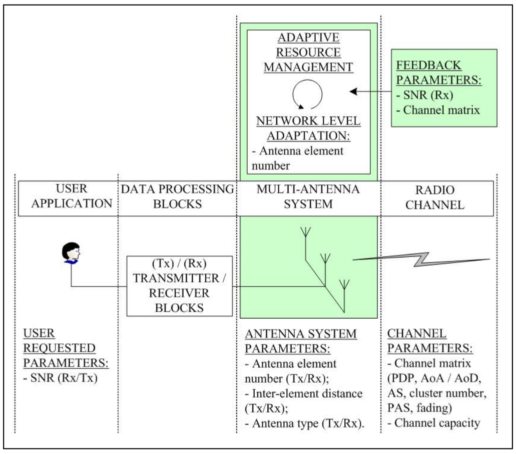

Figure 5: Air interface parameters and feedback information in a multi-antennas system.

by a RMS delay spread of 30 μsec and 2 clusters, while the later has a larger RMS delay spread of 150 μsec and 6 clusters.

System Requirements: We start showing the importance of an adaptive multi-antennas system by considering that the required channel capacity is 10 bps/Hz. The evaluation is performed for a system that is subject to the radio channel variations within the same propagation environment, but also to the changes between different types of propagation environments.

4.1 Antennas-System Adaptive Potential on the Channel Variation

Because of the variability of the wireless channel, the system configuration that needs to be employed in order to meet the channel capacity constraint (C = 10 bps/Hz) can vary over the SNR domain. The channel capacity variation with SNR, obtained after modeling the channel type C for all antenna combinations, is depicted in Figure 6.

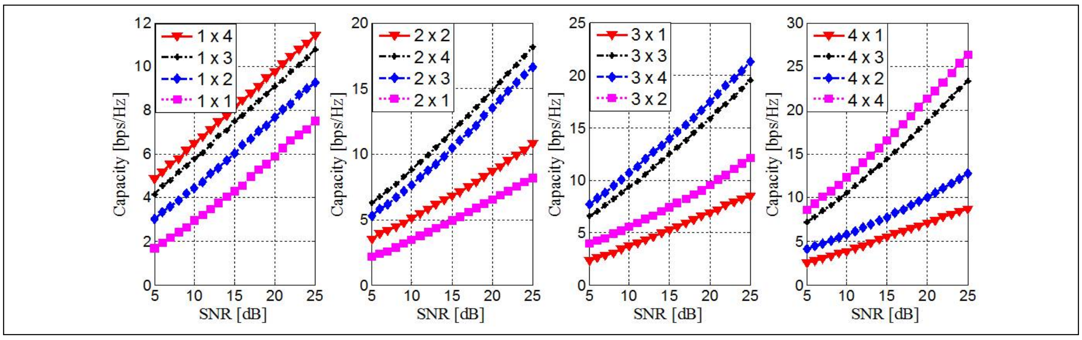

Figure 6: Channel C capacity (bps/Hz).

Table 3 gives the optimal configuration when the system has only CSIR (Channel State Information at Receiver) and considering that the transmitter has a fixed number of antenna elements, from 1 to 4. When the transmitter has only one antenna, the capacity constraint could be fulfilled only if the signal-to-noise ratio is high (in the range of 20 to 25 dB) and the number of receive antennas is 4. For this situation, the capacity constraint cannot be fulfilled when the channel state aggravates, so a higher number of transmit elements would be needed (e.g. 2 or in some cases even 3 or 4). For lower SNR domains, a higher order configuration needs to be employed in the system than for the situations with a higher signal-to-noise ratio.

SNR (dB)	5-9	10-14	15-19	20-25
Tx=1	-	-	-	Rx=4
Tx=2	-	Rx=4	Rx=3	Rx=3
Tx=3	Rx=4	Rx=3	Rx=3	Rx=2
Tx=4	Rx=4	Rx=3	Rx=3	Rx=2

Table 3: CSIR MIMO configurations for C=10bps/Hz.

In order to make sure that the required channel capacity is satisfied even under bad channel conditions, the system needs to be reconfigurable. To that effect, a feedback link to the transmitter must exist in order to properly decide which is the most suitable configuration that can be used to assure the required channel capacity. On the other hand, if the system had CSIT, the posible needed configurations would be as the one proposed in Table 4; the configurations are chosen so that the receiver would have the minimum number of active antennas.

SNR (dB)	5-9	10-14	15-19	20-25
Tx x Rx	3 x 4	3 x 3	2 x 3	4 x 2

Table 4: CSIT MIMO configuration for C = 10 bps/Hz, model C

On the assumption in [16], the costs of 2×2 and 4×4 reconfigurable MIMO system are 1.5 and 2.5, respectively, times the cost of a SISO (Single Input Single Output). For this reason, the required feedback information at transmitter shown in Table 4 is correlated not only for guaranteeing the minimum required channel capacity, but also to meet the cost reasons.

4.2 Antennas-System Adaptive Potential Based on Channel Characteristics

The MIMO system reconfiguration can also be requested when the propagation environment changes (e.g. from a small office to a large space), under the same channel capacity constraints.

In the F channel type, due to its characteristic propagation parameters, the spatial correlation degree at transmitter and receiver are different from those in the C channel type [17]. As a consequence, the MIMO system configurations that guarantee a C = 10 bps/Hz at different SNR domains are different than those used in the first propagation environment. Assuming that the feedback link exists in the MIMO system, the employed configurations in model F are analogously specified in Table 5.

SNR (dB)	5-9	10-14	15-19	20-25
Tx x Rx	3 x 4	4 x 3	3 x 3	3 x 2

Table 5: CSIT MIMO configuration for C = 10 bps/Hz, model F.

As a consequence of the variability of the wireless communication channel, of the mobility of the end users within the same channel environment and to other propagation surroundings, there must exist a reconfigurable MIMO system at transmitter and receiver in order to meet the application constraints.

In this section it was shown the importance of MIMO air interface reconfigurability at both transmitter and receiver such that the imposed channel capacity (which in turn is related to the maximum amount of information that can be reliably transmitted over the bandwidth of the communication channel) can be satisfied regardless the SNR values and the propagation environment. An important condition that can allow the reconfigurability at the transmitter is the presence of a feedback channel that transports the required channel state information (e.g. channel matrix, SNR) in concordance the reconfiguration is performed with.

The advantages of a feedback channel are emphasized in the following, considering a MIMO system that operates in channel C type. For these analyses, we start from the same system requirements conditions, which impose a minimum channel capacity of 10 bps/Hz. In addition, we consider a SNR level of 20 dB. From Tab.4 the required antennas configuration that can satisfy these two restrictions is 4×2.

5 Adaptive Potential of Spatial Transmitting Processing Techniques

The achievable performances enhanced due to the use of spatial processing techniques depend on the nature of the channel state information (CSI) available at the transmitter and receiver [18].We assume perfect CSI at the receiver and evaluate the adaptive potential of the system considering that either channel quality indicator (CQI) (received SNR), or statistic channel information (channel mean) can be exploited at the transmitter. The idea is to adapt the application requests, according to the capabilities of the network at the physical layer.

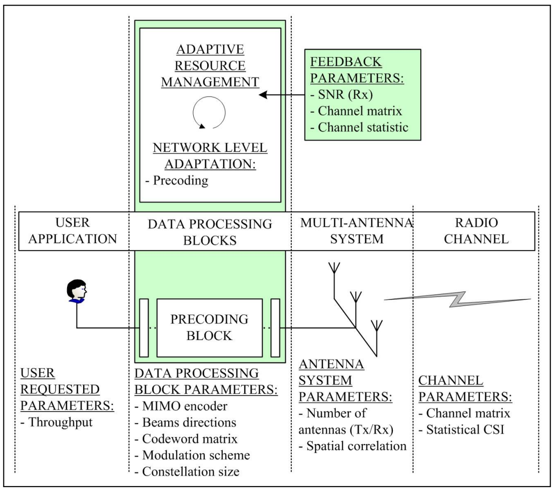

Figure 7: Adaptive potential of spatial transmit processing techniques.

The amount of channel knowledge at the transmitter has a direct influence on the adaptive adjustment capability of the system. It establishes the design parameters that can be adapted to different channel conditions. As they are mentioned in Figure 7, in the data processing blocks, the parameters are: the MIMO transmission technique, the codeword matrix, the modulation scheme and the constellation size, the beams direction, the power allocated to each beam, subject to a total transmit power constraint.

5.1 Multi-Antennas System Adaptive Potential through MIMO Encoding Scheme

The approach is based on switching between different transmission algorithms, depending on the variable channel condition, in order to provide the application with the requested QoS profile.

System parameters: We consider an uncorrelated 2×2 MIMO system, a 4-PSK modulation and a quasi-static flat fading channel model. Two open-loop encoding techniques are to be used at the transmitter: STC (Space-Time Codes) [19], [20] which improve the link reliability thanks to transmit diversity, and SM (Spatial Multiplexing) [21] used to increase the peak error free data rate by transmitting separate data streams from each antenna. At the receiver, optimal ML (Maximum Likelihood) detection is performed in both cases. The packet length considered for the throughput computation is 200 bytes.

System requirements: The application requires a minimum throughput value of 1 Mbps.

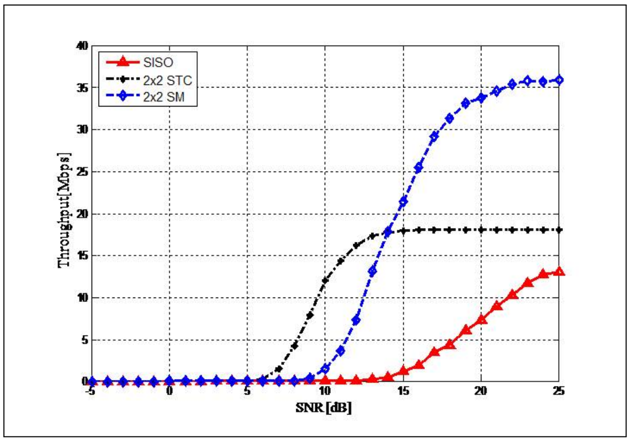

Figure 8: Capacity gain in multi-antennas systems with perfect CSIT.

Based on the CQI, the transmitter can select the MIMO encoding scheme that maximizes the throughput link. As it can be depicted in Figure 8, the throughput switching point, for a 2×2 MIMO system, is around a SNR = 14 dB. At low to medium values of the SNR, STCs provide a highest throughput due to their robustness against poor channel conditions. At high values of the SNR, SM is the best choice as it provides a high error-free data rate.

5.2 Multi-Antennas System Adaptive Potential by Optimal Power Allocation

System parameters: In Section 4 it was shown that, if the MIMO channel follows the IEEE 802.11n C design model, in order to ensure a minimum capacity value of 10 bps/Hz, at a SNR = 20 dB, a possible transmit/receive antennas configuration is 4×2. In this section, based on the same antennas configuration, we evaluate the capacity gain that is obtained if the transmitter has perfect CSIT [22].

System requirements: Channel capacity maximization with an efficient use of the radio resources.

The transmitter relies on perfect CSIT to distribute the available transmit power based on the channel modes. Through waterfilling (WF) more power is allocated to the strongest eigenmodes, as it can be depicted in Figure 9, whereas without CSIT, the power is equally divided (EP Equal Power) between the transmit antennas. The capacity gain due to CSIT is significant, reaching 2.5 bps/Hz at a SNR = 20 dB for a spatially correlated 4×2 MIMO system. Due to efficient use of the transmit power, through optimal power allocation, a minimum capacity of 10 bps/Hz can be ensured with the same number of transmit and receive antennas (4×2), even if the SNR value decreases to 12 dB.

5.3 Multi-Antennas System Adaptive Potential through Linear Precoding

System parameters: We consider MIMO systems having the same diversity order, an

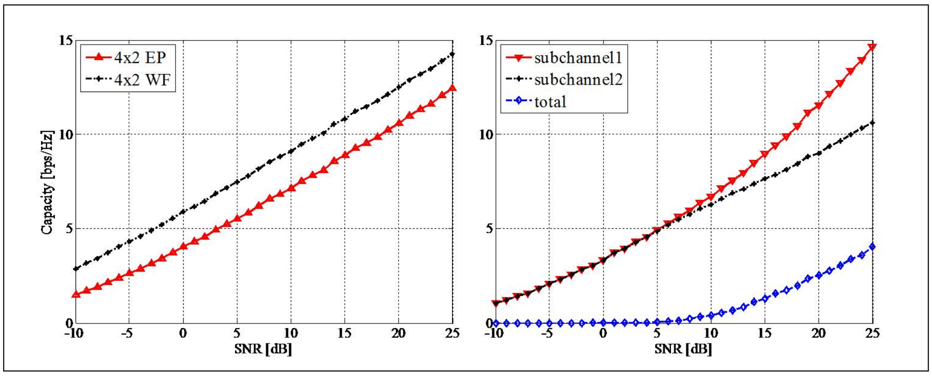

Figure 9: Capacity gain and power allocation in a correlated 4×2 system with perfect CSIT.

uncorrelated flat fading channel model and a ML detection. The transmitter uses STBC (Space-Time Block Codes), a special case of space-time codes. A combination of STBC codeword matrices, characterize by their coding rate, and modulation schemes are selected in order to ensure a spectral efficiency of 2 bits/s/Hz for each MIMO transmission. Also, we consider that, through a feedback channel, an estimated channel matrix is available at the transmitter [23].

System requirements: The imposed application requests a minimum throughput value of 5 Mbps, which has to be satisfied also for low SNR values. In order to fully exploit the presence of multi-antennas, the linear precoding aims to adapt the transmitted signal to the channel state, by adjusting the beams directions and the power allocated to each beam. In [23] it was shown that, the data preprocessing is based on the noise variance, the eigenvalues of the estimated channel matrix and the eigenvalues of the codeword error matrix.

The simulation results are depicted in Figure 10. Both CSIT and no CSIT transmissions were considered. For the precoder design it is assumed a small CSIT error. Without adaptation, for low values of the SNR, the application requirements are satisfied by the system using 2 transmit antennas and 4-PSK modulation as it is more robust against noise. If the channel condition is available at the transmitter, by means of precoding, the transmit data can be adapted to the channel state. The highest throughput improvement is obtained for the systems with a higher number of transmit antennas. A link throughput value of 5 Mbps can be provided by the 4×4 MIMO precoded system, if the channel quality indicator is above -5 dB, while without adaptation, a minimum of 1 dB is needed to fulfil the same requirements. In the case of a 4x2 system, the SNR gain for the same throughput is about 3 dB, while for the 2×4 the SNR gain is only 1 dB.

Regarding the adaptive potential, channel knowledge at the transmitter is essential in the low SNR region and can be efficiently exploited in high transmit diversity systems.

6 Adaptive Potential of the Application Parameters

The model used to demonstrate the adaptive potential of the application parameters through network virtualization is the I-NAME (In-Network Autonomic Management Environment) QoS model, a model that calibrates the source application requests to the available network resources [24]. For the I-NAME model, the network virtualization process is assisted by the QoS profiles, a set of messages including QoS parametric description of resources.

Network virtualization process assumes similar parameterization of resources in terms of delay, throughput and jitter, both for application and network elements, as presented in Figure 11. The application QoS profile encapsulates the parameters initially requested by the source

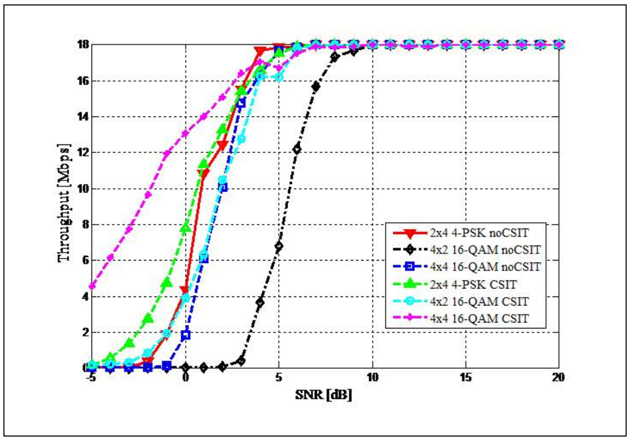

Figure 10: Throughput enhancement in precoded multi-antennas systems.

application, further identified in the network and finally agreed for a virtual network established between the source and the destination node. Assuming that multiple virtual networks may share the same overlaying physical network infrastructure [25], the network QoS profile involves the identification and selection of network elements that integrate the application's specific requests for resources. Based on the use of QoS profiles message exchange, the I-NAME model indicates the best path to the destination in terms of the selected virtual network elements and of the most appropriate source application configuration settings, through adaptation.

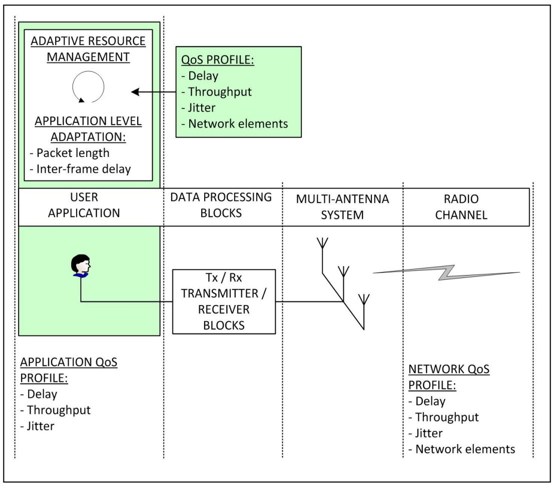

Figure 11: Adaptive potential of the application parameters.

System Parameters: To demonstrate the adaptive potential of the application parameters, we test the behaviour of time-critical applications under specific network conditions: with the I-NAME QoS support model for adaptation, over a BE (Best-Effort) network support, and based on QoS network layer classification (IP Precedence 3 and 6). Different application behaviours were modeled by varying the packet size in the source application between 200 and 1600 bytes. Using QualNet Developer 4.5, a network scenario which models two radio access segments (IEEE 802.11 and 802.16) connected through a core network segment composed by multiple wired or wireless connections was built. The source application was located in the IEEE 802.11 network segment, while the destination node was located in the IEEE 802.16 access segment.

System Requirements: The requirement for resources is included in the application QoS profile in terms of a minimum requested delay of 0.01 sec and a minimum requested jitter of 0.1 sec.

As we have already mentioned, the conjunction between the source application requests and the network context is achieved through the QoS profiles message exchange and it represents the process of network virtualization. Even the improvements added by the I-NAME QoS model through network virtualization are significantly better compared to the support offered by the other models, the results presented in Figure 12a indicate the overcome of the minimum imposed average end-to-end transmission delays value of 0.01 sec in 40% of cases for variations of the number of packets transmitted per second.

When the application requirements exceed the network capacity, the I-NAME model proposes an adaptation of the application parameters: through source fragmentation or by source code adaptation. The coding adaptation procedure of the source application implies increasing the interval between packets sent by the source application to the value <interval*2> while maintaining the transmitted packet size for all the cases in which the surpassing of the maximum accepted average delay value is indicated. After the coding adaptation process is applied, application's average end-to-end transmission delay is kept within the imposed limits by the QoS profile, as illustrated in Figure 12b.

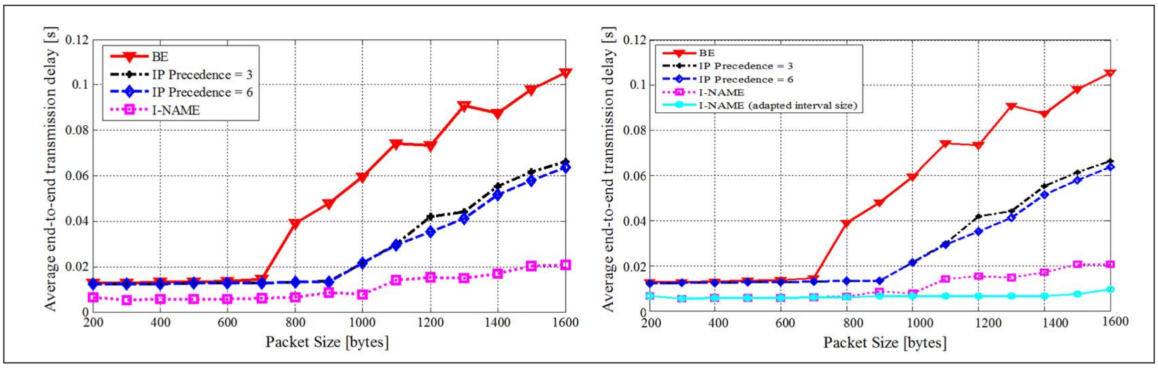

Figure 12: (a) The effect of I-NAME QoS support upon the average end-to-end delay variation (left), and (b) The effect of I-NAME adaptation process through source code adaptation (right).

Therefore, the adaptive potential of the application parameters involves network virtualization with respect to the imposed application QoS profile and gradual adaptation of the source application by means of source fragmentation or source code adaptation.

7 Conclusions

The scope of this paper was to identify, explore and propose adaptive techniques that can be used for achieving an efficient resource management, in the attempt to enhance the transmission quality of wireless systems. The presented adaptive solutions have illustrated the capability to efficiently use the available system resources, by applying different techniques based on a feedback loop or on network virtualization. For systems using a feedback loop, the adaptive potential on resource management was explored through modulation and coding schemes calibration, multi-antennas system configuration, optimal power allocation strategies or through linear precoding. Through the network virtualization process, the adaptive potential at the application level is emphasized, by applying source fragmentation or source code adaptation. Thus, by realizing adaptation at either the network level or application level, all these techniques guarantee an efficient resource management in wireless systems.

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Bibliography

[1] M. Mueck, A. Piipponen, G. Dimitrakopoulos, K. Tsagkaris, et al., ETSI reconfigurable radio systems: status and future directions on software defined radio and cognitive radio standards, *IEEE Communications Magazine*, ISSN 0163-6804, 48(9):78-86, 2010.

[2] N. Crisan, C. L. Cremene, E.Puschita, T. Palade, Evaluation of Adaptive Radio Techniques for the under-11GHz Broadband Wireless Access, *INT J COMPUT COMMUN*, ISSN 1841-9836, 3(S):232-237, 2008.

[3] M. Tran, G. Zaggoulos, A. Nix, A. Doufexi, Mobile WiMAX: Performance Analysis and Comparison with Experimental Results, *IEEE 68th Vehicular Technology Conference (VTC)*, 1-5, 2008.

[4] Y. Hang, Z. Lin, S. Ashutosh, Power Management of MIMO Network Interfaces on Mobile Systems, *IEEE Transactions on Very Large Scale Integration Systems*, 20(7):1175-1186, 2012.

[5] A. Doufexi, E. Tameh, A. Nix, A. Pal, M. Beach, C. Williams, Throughput and Coverage of WLANs Employing STBC under Different Channel Conditions, *1st International Symposium on Wireless Communication Systems*, Mauritius, 20-22 September 2004, 367-372, 2004.

[6] J. Salazar, I.Gomez, A. Gelonch, Adaptive Resource Management and Flexible Radios for WiMAX, *Journal of Telecommunications and Information Technology*, 4:101-107, 2009.

[7] WiMAX Forum, *Forum Mobile System Profile Specification: Release 1.5 Common Part*, Revision 0.2.1: 2009-02-02.

[8] Recommendation ITU-R M.1225, *Guidelines for evaluation of radio transmission technologies for IMT-2000*, 1997.

[9] Project BROADWAN - Broadband services for everyone over fixed wireless access networks, *Deliverable 21. Planning guidelines for broadband access networks with case studies*, May 2006.

[10] B. Baumgartner, M. Reinhardt, G. Righter, M. Bossert, Performance of Forward Error Correction for IEEE 802.16e, *Proc. of the 10th International OFDM Workshop (InOWo)*, Hamburg, Germany, 2005.

[11] M. Tran, A. Nix, A. Doufexi, Mobile WiMAX MIMO Performance Analysis: Downlink and Uplink, *IEEE 19th International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*, Cannes, 15-18 September 2008, 1-5, 2008.

[12] L. Zhinin, Z. Wenjun, X. Youyun, An Improved Simulator for the Correlation-based MIMO Channel in Multiple Scattering Environments, *Wireless Personal Communications*, 52(4):777-788, 2009.

[13] E. Vinko, et.al., *IEEE P802.11 Wireless LANs TGn channel models*, doc: IEEE 802.11-03/940r4.

[14] I. Schumacher, K.I. Pedersen, P.E. Morgensen, From antenna spacing to theoretical capacities guidelines for simulating MIMO Systems, *Proc. PIMRC Conf.*, 2:587-592, 2002.

[15] S. Durrani, M.E. Bailkowski, Effect of angular energy distribution of an incident signal on the spatial fading correlation of a uniform linear array, *Microwaves, Radar and Wireless Communications MIKON*, 2:493-496, 2004.

[16] D. Lasevla, I.Z.Kocacs, L.M. Del Apio, E. Torrecilla, Feasibility and deployment analysis of the SURFACE concept, deliverable 1.1, 2009, available at: http://www.ist-surface.org/deliverables/SURFACE-D8.320v1.1.pdf.

[17] I. Vermesan, A. Moldovan, T. Palade, R. Colda, Multi Antenna STBC Transmission Technique Evaluation under IEEE 802.11n Conditions, *15th IEEE International Conference on Microwave Techniques*, COMITE 2010, 51-54, 2010.

[18] M. Vu, A. Paulraj, MIMO Wireless Linear Precoding, *IEEE Signal Processing Magazine*, 24(5):86-105, 2007.

[19] V. Taroch, H. Jafakhami, R. Calderbank, Space-Time Block Codes from Orthogonal Designs, *IEEE Transactions on Information Theory*, 45(5):1456-1467, 1999.

[20] V. Taroch, N. Seshadri, R. Calderbank, Space-Time Codes for High Data Rate Wireless Communication: Performance Criterion and Code Construction, *IEEE Transactions on Information Theory*, 44:744-765, 1998.

[21] G.J. Foschini, Layered Space-Time Architecture for Wireless Communication in a Fading Environment When Using Multiple Antennas, *Bell Laboratories Technical Journal*, 1(2):41-59, 1996.

[22] I.E. Telatar, Capacity of multi-antenna Gaussian channels, *European Transactions on Telecommunications*, 10:585-595, 1999.

[23] W. Huang, E.K. Au, V.K.N. Lau, Linear Precoding for Space-Time Coded MIMO Systems using Partial Channel State Information, *IEEE International Symposium on Information Theory*, 391-395, 2006.

[24] E. Puschita, T.Palade, A. Moldovan, R.Colda, I. Vermesan, An Innovative QoS Paradigm based on Cognitive In-Network Management of Resources for a Future Unified Network Architecture: I-NAME QoS Model, *The Second International Conference on Advances in Future Internet AFIN 2010*, ISBN 978-0-7695-4091-7, 37-43, 2010.

[25] A.G Prieto, D. Dudkowsky, C. Meirosu, C. Mingardi, G. Nunzi, M. Brunner, R. Stadler, Decentralized In-Network Management for the Future Internet, *IEEE International Conference on Communications*, ICC09, 1-5, 2009.