Enabling Multimode Wireless Access Networks Using Remote Radio Heads

Georgios Kardaras[1], Jose Soler[2], and Lars Dittmann[2]

[1] Radiocomp ApS
Krakasvej 17, 3400 Hillerød, Denmark
gka@radiocomp.com
[2] Networks Technology & Service Platforms Group
Department of Photonics Engineering,
Technical University of Denmark, 2800 Kgs. Lyngby, Denmark
{joss,ladit}@fotonik.dtu.dk

Abstract. The deployment of 4G networks is spreading rapidly providing mobile broadband services to the public. 4G technologies are designed to overlay existing 3G networks enabling reusability of several network components. In this way, the coexistence of 3G/4G standards is facilitated. This paper describes the advantages of using distributed base station architectures to provide multimode capabilities. In particular, it focuses on the radio unit, commonly known in industry as remote radio head. Multimode radio units capable of operating according to different wireless standards (WCDMA, LTE and WiMAX) can be proven extremely beneficial for operators especially in terms of operational and maintenance cost. Moreover, remote radio heads can enable effective spectrum management and allocation of radio resources. This is achieved through the advanced software configurability they provide and a flexible control and management plane. Switching between wireless standards becomes easily feasible through firmware upgrading. Finally, real-time configuration of radio functionalities, such as transmit power, receiver gain, carrier frequency, channel bandwidth and others result in a modular software defined radio platform.

Keywords: software defined radio, multimode radio, optical fibre, 4G communication, WiMAX, LTE.

1 Introduction

The demand for high speed broadband wireless access at low prices has been explosive the past years. Modern cell-based broadband wireless standards such as WiMAX and LTE are capable of fulfilling this demand. However, the cost of upgrading infrastructure is massive. Distributed base station architectures are able to resolve this challenge to an extent through the multimode capabilities they provide. Deploying this type of architectures allows operators to support multiple wireless standards sharing the same radio platform. This is achieved by separating physically the baseband from the radio functionalities combined in a base station design.

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This paper concentrates on the remote radio unit, known as remote radio head. The benefits and limitations of this network component are described as far as multi-standard support, maintenance and upgrading are concerned. Firstly, the concept of distributed base station architectures is presented. The top-level design is briefly described and the major interfaces are discussed. The next step is to analyze more specifically the functionalities of remote radio head and the reasons they can facilitate multimode operation in modern wireless access networks.

2 Delivering Wireless through Fiber

In distributed base station architectures the two major network components are the baseband server and the remote radio head unit. The base station server is connected to the remote radio head through an optical fiber. This enables the remote radio head to be situated up to 15km away from the base station server adding substantial flexibility to network designing. The optical link is used to distribute modulated baseband wireless data of any standard to the remote radio head which is placed on the antenna tower very close to the antenna unit. This is possible because of its relatively small size and low weight. In average a remote radio head weights less than 15 kilograms and its size does not exceed 20x30x50cm, making it easy to install or replace.

On the contrary, in conventional base station architectures the RF wireless signals reach the antenna sites through copper feeders. This approach is expensive in power losses and signal attenuation. It is estimated that over 25% of power is consumed before being radiated over the air [5]. In addition, space for hosting and cooling the base station in the surroundings of the antenna tower is also necessary. This results in increased capital and operational expenditure.

Architectures based on remote radio heads exploit the advantages of radio over fiber systems (high bandwidth, low signal attenuation, lightweight materials) providing at the same time the necessary interfaces for remote control and management. In this way, the result is a fully configurable software defined radio node able to adapt in real-time to specific network requirements. It is agnostic to the wireless standard used, since the baseband data travelling over the fiber are already modulated. Therefore, the same radio hardware platform can be reused for multiple wireless standards after the necessary software upgrade.

However, necessary prerequisite for distributed architectures to function properly is the definition of a protocol between the baseband server and the remote radio head. In particular, there are two initiatives defining the appropriate interfaces and restrictions. The Open Base Station Architectures Initiative (OBSAI) and the Common Public Radio Interface (CPRI) have been introduced and supported independently by different network equipment vendors [7, 8].

These protocols provide a reliable communication link between the two nodes on the physical layer. They incorporate several functionalities enlisted in Table 1. As expected, multimode is supported by defining various mapping schemes for GSM/EDGE, WCDMA, WiMAX and LTE. Additionally, multiple antenna carriers are defined in the same frame for multi-standard multi-carrier radio transmission.

In this way, spectrum can be divided and managed efficiently according to operator's needs and regulations. In addition, another important feature of CPRI and OBSAI is the fact that they provide a dedicated Ethernet channel for the control and management of the remote radio head node. This means that the radio unit can be configured and monitored on an air-frame basis, for example every 5 or 10ms depending on the standard. This minimizes the response and adaptation time the radio hardware needs to enable new configurations. Thanks to this "embedded" control and management channel, a separate channel for control purposes through another type of cabling is no longer necessary. Both user data and control data are enhanced in the CPRI or OBSAI frame and transmitted through the optical fiber.

Table 1. Physical Layer for Distributed base station architectures

Protocol	Functionalities
OBSAI/CPRI	Electrical and optical signalling
	Synchronization and clock recovery
	Timing information and network topology
	Framing
	Delay calibration
	Reliable forwarding of baseband data
	Control management plane for remote radio head nodes

3 Functional Decomposition

It is essential to describe the way functionalities are decomposed between the baseband server and the remote radio head to clearly understand how and why multimode radio access is facilitated. The baseband server is responsible for providing interfaces to the backhaul network from one side and the remote radio head to the other side. It provides the same digital functions with a conventional base station including the control and management of the remote radio head. These functions involve backhaul transport, channel coding, interleaving, modulation, MIMO management and others. The difference with conventional base station is that all analogue and radio frequency functions, such as filtering, frequency conversion, and amplification have been moved to the remote radio head. Table 2 gives an overview of this functional decomposition specific for WiMAX applications.

Based on the functionalities a remote radio head incorporates, we observe that it is a transparent node, independent of the wireless standard used. However, it needs to be configured for supporting different channel bandwidths, sample rates and antenna carrier frequencies [2]. The configuration of the mentioned system parameters is done purely through software. Switching between standards is feasible as well as their coexistence in different antenna carrier frequencies. In this way, spectrum can be managed efficiently based on traffic characteristics, user demand or geographical constraints. The multimode and multi-carrier properties of remote radio heads become a very useful tool for operators, since they provide full control over the assigned spectrum.

However, there are some factors which limit the multimode operation of remote radio heads. The first concerns the multiplexing technique defined by the wireless standard. More specifically, WiMAX specifications define Time Division Duplex (TDD) as the multiplexing technique to be used. On the other hand, the multiplexing technique for LTE can be either TDD or Frequency Division Duplex (FDD), allowing even more flexibility. Remote radio heads can only support one multiplexing technique at a time. In case of TDD applications, the transmit and receive paths share the same RF frequency but transmission and reception take place in different time slots, defined by TDD switching. This has several advantages with most important the asymmetrical downlink and uplink data speeds. This means that the downlink and uplink speeds can be dynamically adjusted according to network or user equipment requirements. Allocating bandwidth in this flexible manner can save radio resources and optimize network planning. In case of FDD applications, the remote radio head is equipped with RF components tuned to operate in different transmit and receive carrier frequencies separated by a guard band to minimize interference. It becomes obvious that multimode radio operation is not feasible in case the multiplexing technique varies. However, it is commonly accepted that operators customize the standards according to their strategies, choosing a multiplexing technique suitable for their network.

Table 2. Functionalities of baseband server and remote radio head for TDD WiMAX applications [8]

Baseband server Functionalities		**Remote Radio Head Functionalities**	
Downlink	Uplink	Downlink	Uplink
Remote Radio Head control and management		Channel filtering	
Backhaul transport		D/A conversion	A/D conversion
MAC layer		Digital up conversion	Digital down conversion
Channel coding	Channel decoding	Control of antenna carriers	Automatic gain control
Interleaving	Deinterleaving	Carrier multiplexing	Carrier demultiplexing
OFDMA Modulation	OFDMA Demodulation	Power amplification	Low noise amplification
MIMO management		TDD switching	
Signal measurements		RF filtering	

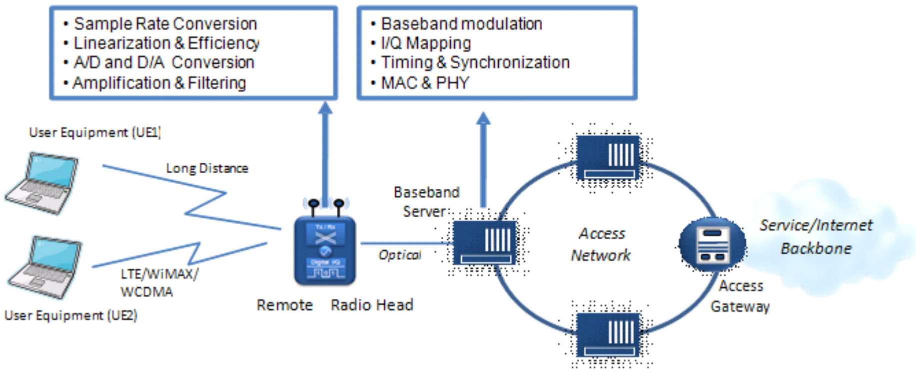

Fig. 1. Overview of distributed base station architecture

The second limitation also originates from the RF hardware platform. This restriction concerns the front-end RF filtering. These filters are precisely tuned to specific RF frequencies. This allows the remote radio head not to cause interference to adjacent frequency bands or being interfered by them. The range each front-end filter covers depends on the specification of the component and it cannot be modified dynamically during operation. This range defines the number of antenna carrier frequencies a remote radio head can provide. For example, a 50MHz front-end filter tuned at 2.5GHz could theoretically provide carrier frequencies between 2.48GHz and 2.52GHz, supposing that the channel bandwidth of the transmit signal is 10MHz. This constraint forces remote radio head vendors to design different modules for each frequency variant. Multimode operation is affected in case the operator decides to maintain persistent radio frequencies for each wireless standard. However, spectrum management can be substantially facilitated by the fact that user equipment is designed to scan several frequency bands, until it discovers the one where it can become operational.

4 Conclusions

This paper discussed the use of distributed base station architectures for enabling multimode capabilities in modern wireless access networks. In particular, the advantages provided by remote radio heads are described. This approach combines the benefits of radio over fiber and software defined radio systems. The distributed nodes are interconnected via optical fiber which offers flexibility in terms of network topology, bandwidth, power loss and interference. Moreover, the remote radio unit can be monitored and configured real-time through the protocols defined, CPRI and OBSAI. Another essential characteristic is that it remains agnostic to the wireless standard used. This allows reusing the same radio platform for different 3G/4G applications by performing only software upgrades. In this way, operators are able to shape strategies and introduce policies for managing spectrum and allocating radio resources. Additionally, the flexibility remote radio heads provide results in a smooth and cost-effective migration to new technologies.

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