Cognition Based Reconfigurable Wireless Network Technology

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Abstract:
The End-to-End Reconfigurability (E2R) project aims at realizing the convergence of the heterogeneous radio networks and the optimal utilization of the radio resources. With the continuous development of E2R technology and cognitive theory, the evolution from existing radio networks to future reconfigurable radio networks with the cognitive ability becomes possible. Nowadays the research aspects of E2R include the system architecture of reconfigurable radio networks and some key technologies for their evolution.

As a result of thriving development of wireless communication technologies, heterogeneous networks emerge, which not only diversifies network services, but also brings lots of problems for network management and technical evolution. To meet the users' needs for global roaming and make full use of network resources, there is an increasing demand for interoperability and convergence of heterogeneous technologies. Such a demand promotes the development of End-to-End Reconfigurability (E2R) research.

With theoretical research of reconfiguration deepening and theory of reconfigurability being closely combined with cognitive theory, an important subject in the research of heterogeneous wireless networks would be how existing wireless networks can gracefully evolve into cognitive reconfigurable heterogeneous wireless networks.

1 Reconfigurable Technology Overview

E2R technology originated from Software Defined Radio (SDR) technology. It defines the system architecture based on reconfigurable entities such as terminals and base stations, and achieves adaption to heterogeneous environment and effective utilization of heterogeneous radio resources by combining advanced resource management mechanism and flexible air interface technologies[1]. Reconfigurable technology is a novel technology for heterogeneous wireless network convergence, mainly used for end-to-end reconfiguration of communication systems. E2R means adaptability of the nodes along the complete communication path between communicating entities, encompassing configuration and reconfiguration of equipment (terminals, base stations, access points and gateways) and potential impact on all layers of Open Systems Interconnection (OSI) Reference Model. The E2R engineering has developed a series of concepts and solutions to enable, manage and control end-to-end connectivity in Beyond Third Generation (B3G) heterogeneous environment. The main objectives of E2R research are:

- Providing seamless experience to end-to-end users and operators
- Increasing resilience of complicate network architecture
- Reducing the costs of evolution, deployment and maintenance of large systems
- Enabling new services to be rapidly developed and applied.

1.1 Research on Reconfigurable Technology

Internationally, the research of reconfigurable technology has produced certain achievements. In the Information Society Technologies (IST) programmes funded by European Union (EU), there are over 20 projects that are related to cognitive radio networks, including Configurable Radio with Advanced Software Technology (CAST), Transparently Reconfigurable Ubiquitous Terminal (TRUST), Smart User-Centri Communication Environment (SCOUT), Ambient Networks (AN) and E2R. Among them, E2R project[2-3] is the most mature. It develops a complete system architecture for reconfigurable radio networks, defines necessary functional modules and procedures, as well as studies the impact of reconfiguration function on dynamic network planning and management, flexible spectrum management and joint radio resource management. This project has played a significant role in propelling the research of reconfigurability all over the world. The key achievements of E2R project are the architectures and concepts it devises or

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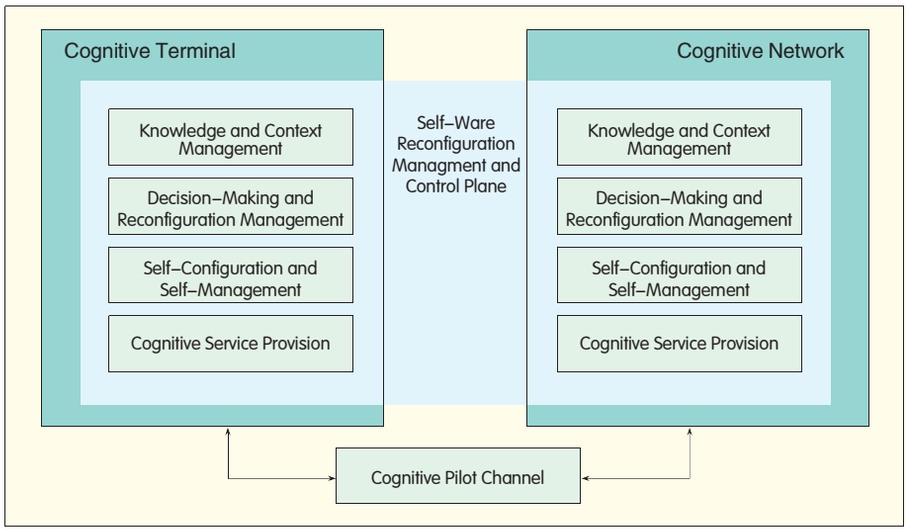

▲Figure 1. Self–ware reconfiguration management and control plane of E2R.

proposes, including:

• E2R system architecture, including mapping onto existing standards

• Self–ware reconfiguration management and control plane

• Functional architecture for optimized exploitation of spectrum and radio resources

• Dynamic Network Planning and Management (DNPM)

• Advanced Spectrum Management (ASM)

• Joint Radio Resource Management (JRRM)

• Cognitive Pilot Channel (CPC).

Meanwhile, some international research institutes and standardization organizations have actively participated in and promoted the research of E2R. In September 2006, the Institute of Electrical and Electronics Engineers (IEEE) established P1900.B Standardization Study Group, focusing on the coexistence support for reconfigurable, heterogeneous air interfaces. In order to ensure coexistence between existing and future radio networks, quick deployment of heterogeneous wireless systems and increase of resource utility, P1900.B defines the system's overall functional architecture and introduces respective reconfiguration management modules into networks, radio interfaces and user terminals. The European Telecommunications Standards Institute (ETSI) and the 3rd Generation Partnership Project (3GPP) have also started the standardization of cognition–based E2R.

1.2 Reconfigurable Network Architecture

A reconfigurable network requires all entities to be adaptive and self–configurable, which poses a great challenge for the heterogeneous network architecture. One main achievement of E2R project is that it proposes the architecture for future reconfigurable wireless networks.

E2R project views autonomic communication as a key feature of next generation mobile communication systems, and is now devising the adaptive reconfiguration management plane[4] as a unified control and management framework for adjusting end–to–end interaction between entities, thus implementing the reconfiguration–enabled mechanisms in dynamic mode.

The adaptive reconfiguration management plane includes a protocol model independent of unknown networks which are made up of software defined service operations. It can be used not only as an extension of existing control and management plane, but also as a new, middle plane for existing control and management plane, which provides extra control and management functions for networks in reconfigurable environment.

In E2R II, to provide network elements (e.g. terminal equipment, base stations and routers) with necessary control and management functions to achieve dynamic autonomous reconfiguration, some improvements have been made on the adaptive reconfiguration management plane[5]. The improved model is called "self–ware reconfiguration management and control plane", which views the entire element as an autonomous entity and offers cross–layer control and reconfiguration functions.

As depicted in Figure 1, the self–ware reconfiguration management and control plane consists of the following four modules and one cognitive pilot channel:

(1) Knowledge and Context Management Module

It processes profile information and reconfigurability classmarking, detects local available resources, executes resource allocation commands and generates behavior reports, for the purpose of optimizing global resources.

(2) Decision–Making and Reconfiguration Management Module

It brings and evaluates dynamic policies or rules. In defining system behaviors, these rules will be used to limit the resource requirements of users and applications in terms of availability and commercialization at a high level. Moreover, this module can generate contexts for self–learning and standardize the autonomous behaviors of reconfigurable devices to make right reconfiguration decisions.

(3) Self–Configuration and Self–Management Module

It converts the reconfiguration modes in the protocol layer and across the layers, optimizes local resource allocation and has self–healing function. Besides, it provides access and security control mechanisms and records reconfiguration results as well.

(4) Cognitive Service Provision Module

It is responsible for related capacity control and service application programs.

(5) Cognitive Pilot Channel[6]

It achieves wireless access in the scenario of multiple operators via "outband" physical channels and "inband" logic channels, and provides contextual cognitive information.

The reconfiguration is implemented with the following steps:

(1) The CPC becomes aware of ambient environment first and collects contextual and internal data;

(2) It decides upon proper reconfiguration behaviors by ways of negotiation;

(3) The system tries to satisfy the user's services and capacity demands based on capacity control and service application programs provided by the cognitive service provision module;

(4) The system implements reconfiguration by adjusting wireless network resources and network elements.

To configure ubiquitous seamless access capability on the above reconfigurable architecture, E2R technology must efficiently support multiple air interfaces in a single adaptive system so as to meet the demands of diverse scenarios. The specific support procedure and design will certainly be a focus in the future E2R technology research.

1.3 Spectrum Management and Radio Resources Management

The main objective of E2R research on effective usage of spectrums and radio resources is to maximize the radio resource utilization, thus enabling seamless experience to mobile users. To attain such an objective, it is necessary to leverage different wireless access technologies, their radio spectrum allocation mechanisms and wireless networks operating on different access technologies; accordingly, E2R defines different resource optimization technologies, evaluates them and integrates them into the unified architecture to allow spectrum allocation more dynamics.

The technologies adopted in E2R cover a wide range, from short–term radio resource allocation within different administrative domains, mid–term dynamic spectrum resource allocation in heterogeneous network of a single operator to complicate allocation and management of radio resources of different operators' access networks. Moreover, this range is extending, which will include the dynamic wireless planning technology that can react to changes of operation conditions and requirements in real time, towards the ultimate goal of long–term allocation of regional resources.

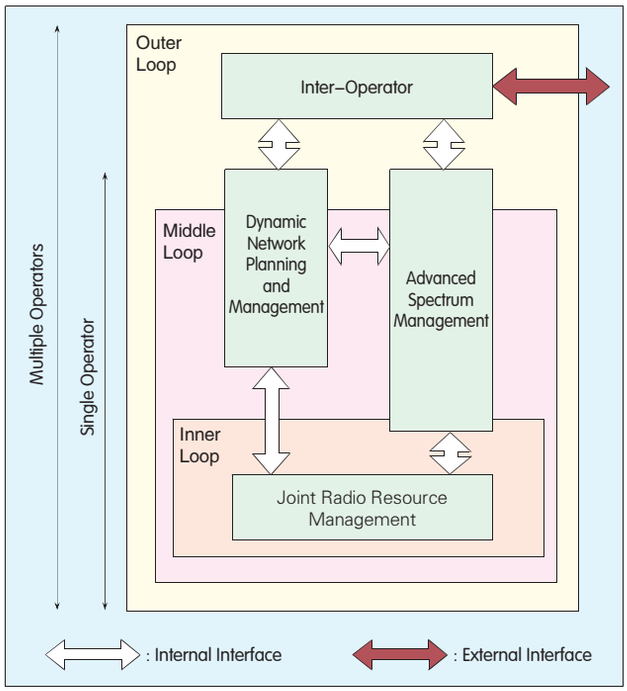

Figure 2. Functional architecture for spectrum and radio resource.

E2R project also studies some dynamic radio resource allocation policies and technologies that function independently, including DNPM, ASM and JRRM. It proposes a framework that is suitable for cases of all levels, such as radio resource allocations in different system conceptions as well as in time and space domains. The objective of such a functional framework is to optimize system mechanism and functionalities in time and space domains where random allocation technologies are used.

The functions of DNPM, ASM and JRRM are illustrated in Figure 2. The three functions interact and correlate with each other. They can be regarded as interlocked loops, where each loop takes reactions based on the output parameters of neighboring loops. The closer a loop is to the system center, the shorter the responding time and the re–allocation time are. From the perspective of an entire system, JRRM, DNPM and ASM need to exchange information, such as base station parameters, traffic measurement in time/space domain, wireless access technical specifications and user parameter selection, in order to effectively operate in a real time mode. In Figure 2, the white arrows refer to the internal interfaces of the network, while the brown arrows refer to the external interfaces.

The main mechanisms in the functional architecture facilitate dynamical allocation of radio resources in different time/space domains and under different loads and requirements. In the time domain, ASM and JRRM are used to process very short– and short–term resource allocation, while DNPM is mainly used to process mid–/long–term dynamic resource allocation in case of multi–access technologies and services.

JRRM is designed to optimize traffic in heterogeneous environment, and it focuses on vertical handover between different access technologies. The ASM is used to optimize spectrum allocation, including optimization of protected bandwidth allocation in heterogeneous environment. DNPM algorithm processes such information as spectrum allocation for wireless access technologies and receivers, user's Quality of Service (QoS) needs and allocation policies required by wireless access technologies based on contexts and related policies. Hence, DNPM adds cross–layer reconfiguration functionality.

E2R also proposes CPC–based scheduling scheme. CPC can act as both a special physical channel and a logic

transmission channel that adopts wireless access technologies. Meanwhile, E2R suggests the one–way information supply method that is from the network to the Mobile Terminal (MT) and the bi–directional information exchange mechanism, which is used for software and policy downloading. With the bi–directional mechanism, MT can use CPC to transmit reconfiguration parameters, detection conditions of channels, links' QoS class and resource selection policy reports. In addition, to maximize the precision of distributed decision–making, CPC is used to transmit policy feedback information.

2 Future Reconfigurable Wireless Network

One important subject in the future E2R research is how to deepen and innovate theories of reconfigurability and apply them in the real networks to achieve graceful evolution from existing wireless networks to the future cognitive reconfigurable heterogeneous wireless networks. However, before reconfigurable heterogeneous wireless networks are deployed, there are many issues to be addressed, including the implementation of the network's autonomous cognitive capability and the application of reconfigurable technology in real networks[7–9].

(1) Autonomous Cognitive Capability of the Network:

As the wireless communication network technologies diversify and become heterogeneous, traditional management methods no longer cater to increasing changes in network environments. To timely react to such changes and optimize network resource allocation, the network should have autonomous capabilities, which have become an important research subject of reconfigurable heterogeneous wireless networks. The autonomous capabilities refer to self–awareness, self–management, self–configuration and self–learning attributes of the network and terminals. Cognitive theory[10] is an important part of the research on the network's autonomous capabilities. With cognitive capability, the communication entities of a reconfigurable wireless network, including terminals, can implement the cognitive process of adaption and self–configuration during communications; the nodes in the reconfigurable wireless networks can achieve information exchange and resource optimization by executing the cognitive cycle.

(2) Application of Reconfigurable Technology in Real Networks:

To exploit the characteristics of various access technologies and to utilize network resources in an optimal way, the components of future reconfigurable wireless networks, including terminals, base stations, access points and gateways, should have the reconfigurable. Based on the heterogeneity of wireless access environments and aiming at optimal utilization of heterogeneous resources and better user experience of services, reconfigurable technology combines programmable, configurable and abstractable hardware environment as well as modularized software design concept, enabling the network and terminals to support various access technologies and be flexibly configured by means of downloading and configuring software and communication protocols.

In addition to development of new business models, openness of policies and support from the regulatory authorities, some technical issues have to be addressed, including architecture and functional module design, equipment management mechanism and procedure, and optimized resource management. With the research on reconfigurable wireless networks going in–depth, new requirements have been imposed on theses issues.

(1) Architecture and Functional Module Design:

Reconfigurable theory emphasizes on the system concept. In order to enable all–sided management of cognitive technology and network elements, existing reconfigurable architecture has to be carefully reconsidered. Specifically, it is required to study the components of network functions, deployment topology of network entities and coupling structure between functions and entities, as well as to design a proactive cognitive reconfigurable network architecture that adapts to heterogeneous network evolution.

(2) Equipment Management Mechanism and Procedure:

E2R means not only the change in wireless access technologies (i.e. modes), but also more specific changes in configuration modes and functions of network equipment. As the technologies evolve, devices such as terminals and base stations will be configured with capability to reconfigure and the capability of cognizing the network and external environment. As a result, the following aspects have to be further studied: the rules for fine granularity decomposition and reorganization of network element functions, the devices' awareness of

external environments, information exchange and negotiation mechanism between several network entities, context collection and management mechanism and related autonomous management procedures.

(3) Optimized Resource Management:

The complementarity of heterogeneous networks in term of technologies results in a tendency to network convergence, whose objective is to make optimal use of network resources in order to improve system performance and user satisfaction. On the one hand, reconfigurable technology allows management and optimization of heterogeneous wireless resources to be more feasible and flexible; on the other, it complicates the system, which leads to more challenges. Optimized resource configuration and utilization is a design goal of reconfigurable wireless network systems and will be realized with management approaches at different levels and of different control granularities. Meantime, advanced effective optimization algorithms and mechanisms are needed.

3 Conclusion

Remarkable achievements have been made in the research of reconfigurable technology in terms of cognitive wireless network architecture and its modules and procedures, dynamic network planning and management, flexible spectrum management and joint radio resource management, but there is still a long way to go in the implementation of intelligent, adaptive cognition and the research of specific technologies. Future research will focus on the autonomous, adaptive and intelligent capabilities of communication entities to develop a new, autonomous, cognitive reconfigurable network system.

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Biographies

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Roundup

ZTE Records 10 Million Terminal Shipments in Q1 2009

ZTE Corporation announced on April 29, 2009 that its terminal products recorded 10 million units shipped globally in Q1 2009, representing an increase of 30% compared with the same period last year. This significant achievement highlights ZTE's leadership in the terminal market, adding significantly to China's position as the fastest growing market globally.

In Q1 2009, 68% of ZTE's terminal shipments were to overseas markets, delivering terminals to over 100 countries and regions. During this time, ZTE's CDMA handsets recorded an impressive 2.5 million shipment in global market, exceeding the total CDMA handsets shipment volume in 2008.

In addition, ZTE provided more than 2 million data cards to the global market in Q1 2009. In 2008, the group shipped 10 million data cards to its worldwide customers, registering a remarkable 426% increase over 2007 and setting a world record as the fastest growing company in the data card market.

ZTE continues to solidify its 3G strategy and has recently launched its newest 3G terminal products for TD–SCDMA, CDMA and WCDMA divided into nine different terminal categories and 40 product types. The latest IT gadgets include mobile handsets, data cards, netbooks, monitors, digital photo frames, wireless phones, home gateways, modules and wireless walkie–talkies which are all parts of the comprehensive array of the company's 3G devices.

(ZTE Corporation)