2

WISDOM Concept and Challenges

The concept of WISDOM is evolved in order to meet the needs of interconnected society by offering ubiquitous terabit wireless connectivity. Based on the novel technologies, systems and network architecture WISDOM is a way towards 5th generation networks which will afford frequencies and data rates up to Tera Hertz and Tera bps, respectively.

WISDOM embodies the basic elements that are the building blocks of the future Internet innovations. The development and evolution of WISDOM offers a basic formula: $\mathbf{E} \sim \mathbf{MC}^{5}$

It is based on the combination of five independent vectors, Communication, Connectivity, Convergence, Content and Co-operation [1] as shown in Figure 2.1.

WISDOM is developed to enable the growth of an interconnected society, bridge the physical and virtual worlds by offering a seamless personalized rich digital experience for the end users, and also creating the optimal conditions for capitalizing on Future Internet innovations.

The top down design of WISDOM can be approached with the help of three founding pillars shown in Figure 2.2 which are [1]:

a) *Information theoretic performance/capacity estimation*:
Different types of networking paradigms will lead the directions for engineering development.

b) *End-to-End performance optimization:*
Protocol design for the end–to-end optimization is very efficient than the ones based on classical layered design.

c) *Cognitive networking principles.*
Self-healing/self-organizing networks based on the above principle are essential to manage both, the complexity induced by a variety of possible usage scenarios and minimization of the spectrum and energy

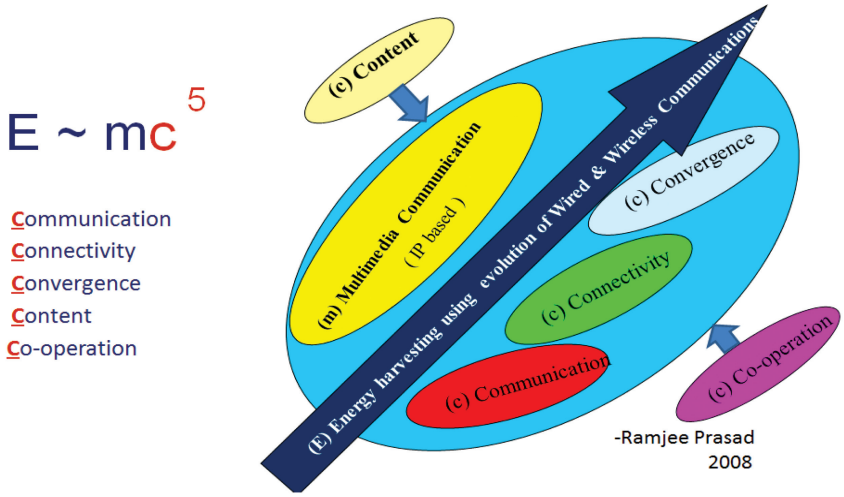

Figure 2.1 WISDOM a new paradigm [1].

Figure 2.2 Pillars of WISDOM [1].

requirements, in order to exploit the spectrum usage. WISDOM uses the concept of "cognitive network (CN)", which is a step ahead of Cognitive Radio.

2.1 WISDOM Objectives

WISDOM aims at enabling wireless infrastructure for the human-centric mega communications in 2020 and beyond. It aims at providing higher capacity and performance than any other current emerging technologies by [1]:

- Designing air interfaces and new systems that achieve a 3 to 5 times improvement over current wireless communications in terms of channel efficiency;

- exploiting larger channel bandwidths in uncontested areas of the spectrum in higher frequency bands and/or considering spectrum co-existence and sharing;
- employing smaller size cells and virtual cells with optimized dynamic spectrum management across different technologies;
- developing novel cross-layer and cross-network domain optimization technologies based on the principles of power efficient cognitive and cooperative communications;
- taking a comprehensive approach in developing a converged WISDOM system by jointly designing radio access systems and network protocols across a number of heterogeneous network architectures including ad-hoc, vehicular, mesh and next generation of cellular networks employing femto-cells and virtual cells efficiently connected to the wired core part of the Future Internet.

WISDOM will also help to design a *converged architecture* as shown in Figure 2.3 and network solution and evaluate its performance with the goal of enabling ubiquitous terabit wireless connectivity for human-centric

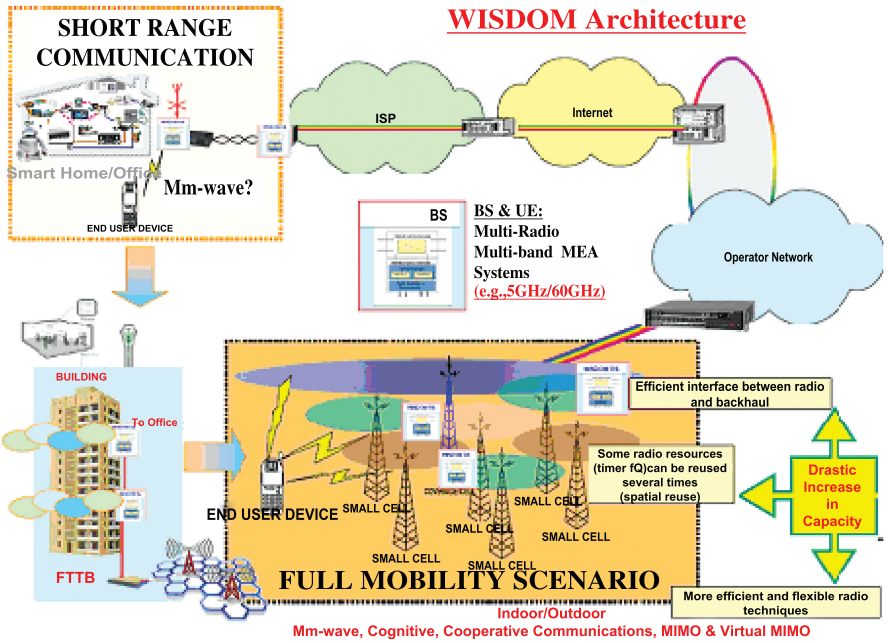

Figure 2.3 Converged architecture of WISDOM [2].

communications over the network of the future. WISDOM will design and develop wireless/wired interfaces and network protocols in order to integrate the wireless access networks to the fixed infrastructure as well as the core optical part of the Network of the Future. It means the focus of WISDOM will be on the design of wireless/wire line interfacing network nodes. These are the nodes that will facilitate the integration of wireless and wired (optical) network segments [2].

2.2 WISDOM System Requirements

In order to implement a WISDOM system the two main requirements are [2]:

- Mechanisms for enabling the transmission of Tera bps.
- Mechanisms for enabling mega communications.

The former can be achieved by the use of new physical layer techniques, such as new radio carrier-less transmission, to identify new spectrum bands, ultra high spectral efficiency mechanisms, MIMO and advanced physical layer (PHY) interfaces and advanced channel coding techniques. Also the new medium access control (MAC) and link layer are required for the strict QoS requirements that would allow the linking source and resource access for trillion device networks.

The latter can be achieved by the novel network protocols and architectures for heterogeneous networks such as femto cells, cooperative transmission, wireless-wired network integration, integration of high capacity satellite links and cognitive radio networks [1].

The 4G technologies together with WISDOM concept will show a way to the wireless communication to realize the true 5G systems.

To summarize [2]:

WISDOM communication interfaces are up to Tera bps link rate in a burst mode for short range communications.

WISDOM has a target of delivering a sustainable rate of 300 Mbps to mobile terminals at high speed for the needs of immersive applications and tele-presence on the move.

2.3 WISDOM Architecture

WISDOM architecture is shown in the Figure 2.4. It has three main components [2]:

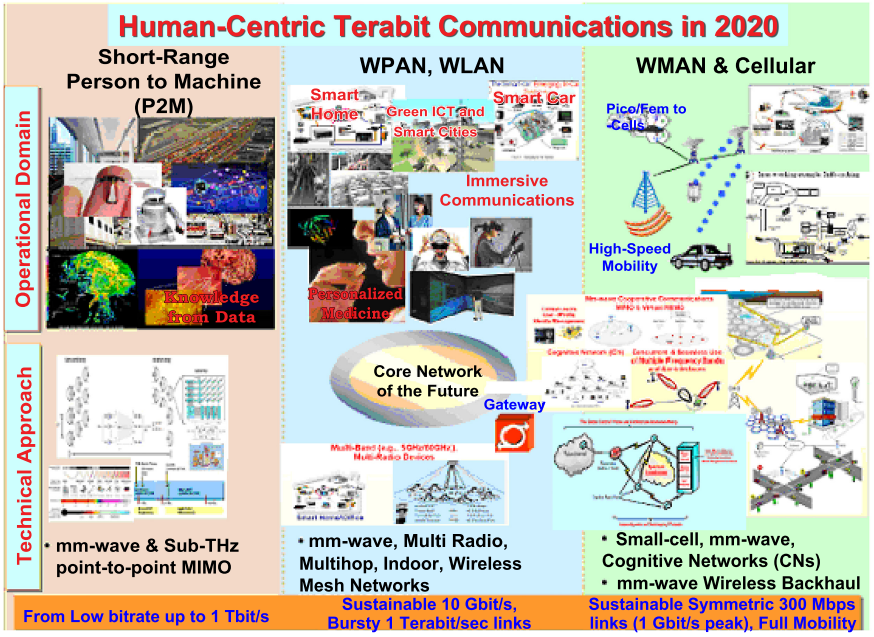

Figure 2.4 WISDOM Architecture [2].

A. Person to Machine (P2M)

The trend of person to machine communication (P2M) is inflaming the bandwidth demand and changes in communication because of its complexity, heterogeneity and integration of new systems and devices using the different network paradigms. These network paradigms consist of network devices ranging from computers, phones both landline and mobile, cameras, PDAs, collection of embedded machines like cars, washing machines, refrigerators, coffee vending machines, all are equipped with wired and wireless applications capabilities.

Applications of this P2M component are IoT, Wireless Sensor Networks (WSN), Mobile Ad Hoc Networks (MANET) etc. which transmits data from low bit rate up to Tera bps.

B. Shortrange

There are different short-range communication application such as smart homes, smart cars, Green Information Communication Technology (GICT) and smart offices, personalized medicines, Radio Frequency Identification (RFID), WLAN, security systems, keyless gates, future Internet, immersive

communication, smart robotics, wireless accessories etc. Characteristics of the short range communication applications are high data rate, very short range, reliability, battery operated transmitters as well as receivers and low cost.

C. Cellular and wide range

The cellular communication system where in perfect cellular coverage occurs if each cell is a hexagon and cells can be arranged in a honeycomb. Most cell towers use Omni directional antennas to data transmit in a circular pattern. In some cases, cells overlap and in others, gaps exist with no coverage.

2.4 Users Requirements and WISDOM

Some of the key enablers of satisfying the user requirements are capacity, connectivity and pervasiveness. These drive the emergence of new environments that evolve from the gradual development and combination of present day cellular communications, IoT and Internet of Services, towards a more advanced vision of fully reprogrammable mobile devices which would make possible to communicate with each other autonomously based on a given event context and part of a scale-free self-organized communication system. Significant breakthroughs in the state-of-the-art are required to reach this level of performance paving us to what can be characterized as a new paradigm for future systems, namely WISDOM [1].

2.5 WISDOM Offerings

WISDOM intends to provide at least an order of magnitude of more capacity than any currently planned wireless radio technology. Creating wireless infrastructure that enables human-centric mega communications is the main aim of WISDOM.

WISDOM gives a novel cross-layer and cross-network-domain optimization technologies based on the principles of power efficient cognitive and cooperative communications. It also offers a design of new air interfaces and systems that achieve a 3–5 times improvement over current wireless communications in terms of channel efficiency. It helps in the exploitation of a large channel bandwidth in uncontested areas of the spectrum in higher frequency bands encouraging the techniques like spectrum co-existence and sharing. WISDOM development offers large evolution [2]:

- Making extensive use of small size cells and the concept of virtual cells, i.e., grouping a number of small cells in a synchronized manner in a way that they all operate in the same channel and are seen by the terminal as a single base station.
- Sharing of knowledge which is used to improve user safety, through intelligent rich presence and collaboration.
- Services for accessibility of users and knowledge based services into workflow and applications, regardless of device.
- Freedom for users to work from home, office or other location using high speed Internet connections.
- A logic based on dependability of services for modularization and locality which operates on "best effort" of technology usage.

2.6 WISDOM Impact

It is already mentioned that WISDOM affords terabit communications with a coverage extending from a city region, to a country, the continents, and the world. This is possible by combining personal- and cognitive radio-networks which is the basic operational concept of WISDOM.

WISDOM enables to capitalize on major innovations towards the future smart infrastructure by integrating under one interoperable umbrella leading technologies, such as advanced M2M communication technologies, autonomic networking technologies, data mining and decision-making technologies, security and privacy protection technologies, cloud computing technologies, with advanced sensing and actuating technologies.

2.7 WISDOM Challenges

The four main operational domains of WISDOM are:

1. Short range low mobility communications
2. Outdoor/Indoor cellular communications with full mobility
3. Converged Architecture
4. Security

The challenges faced by the WISDOM in the above domains are as follows:

Short range low mobility communications

The main target of WISDOM is to provide high data rates of about 1 Tera bps in short range communications. Some of the applications like

smart phones, smart cars, personalized medicines, WLAN security systems, Radio Frequency Identification (RFID), keyless gates, future Internet, robotics, immersive applications, Green Information Communication Technology (GICT) and smart offices other wireless accessories etc. fall under this category.

The key challenges to achieve high data rates in short range distances are [1]:

a) Exploiting the particular bands in the spectrum range from the Extra High Frequency band, that allow for the design of systems that yield high data rate and significant bandwidth efficiency, as required for Tbit/s communications. Band frequency ranging from 70 GHz up to 300 GHz should be considered in particular. Novel and unconventional solutions, both for RF and baseband design should be considered as the traditional design approaches put some limitations on the achievement of 1-Tera bps connectivity. But, the high absorption rate at those high carrier frequencies poses great challenges for their utilization in Non Line of Sight (NLoS) and mobile connections.
   Exploitation of such high frequency bands opens many challenges, among them are:
   - available technology support;
   - channel characterization at those frequencies is lacking;
   - design of robust modulation and transmission techniques has to be done considering Complementary Metal Oxide Semiconductor (CMOS) components limitations;
   - pass band of digital device does not allow to use one channel with a bandwidth higher than 2 GHz today.

b) WISDOM short-range communications are based on multiple directional antennas transmitting to the same terminal in order to create spatial diversity and mitigate Line of Sight (LoS) blocking. Therefore, WISDOM requires novel PHY techniques and also the advancements towards the *cognitive network* architecture. Progress towards this CN concept can be done by carrying out research in a series of interrelated fields such as, directional links, adaptive modulation and coding, medium independent handover, cognitive radio and cooperative techniques at different layers of the protocol stack.

c) *The human-centric paradigm*: This requires a huge interaction of the user with her/his environment in order to interchange information related to the context, profile, role and other relevant information which in general

may help to optimize the whole network behaviour as well as the user perception.

These are the challenges the WISDOM should consider for achieving high data rates in short-range communications.

The scenario of network architecture for short-range communications is shown in the Figure 2.5. It consists of wireless communication systems components such as like CN, WSN, millimetre-wave (mm-wave) cooperative communications, MIMO and virtual MIMO, multi-radio and multi-band devices, multiple frequency bands and air interfaces [2].

There are:

- In mm-wave Communications: MIMO and Virtual MIMO links in the mm-wave bands Different network architectures (Scatter-nets, Multi-hop Mesh, ad-hoc, indoor wireless-wireline connectivity).
- Application points (AP) and User equipment (UE): it consists of mainly three types of wireless devices such as Multi-band, Multi-Radio, and Microwave Endometrial Ablation (MEA).

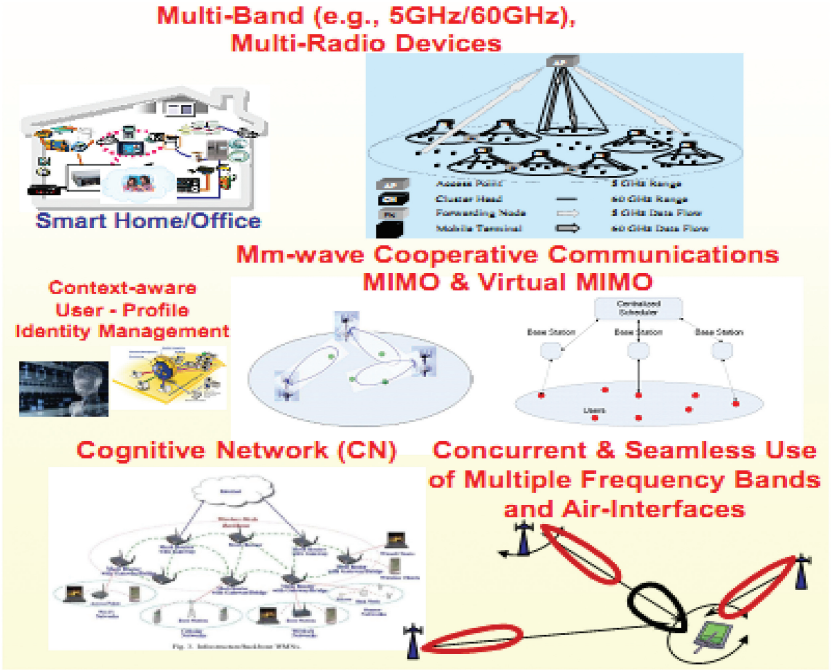

Figure 2.5 Network architecture scenarios for short-range communications [2].

- Different network architectures (Scatter-nets, Multi-hop Mesh, ad-hoc, indoor wireless-wireline connectivity).
- The concept of a CN: it is the combination of computer networks, machine learning, knowledge representation and network management. Cognitive network is a cognitive process which has end-to-end goal which is achieved by following the different network condition, planning, decisions for the different network condition with consequences of the decisions.
- The human-centric paradigm: these devices are configured in such a way that it will give paradigm which will be human centric, e.g., smart homes, offices, cars etc.

Outdoor mobile communications with full mobility

WISDOM aims at delivering a sustainable rate of 300 Mbps to an individual user at full mobility with a peak rate in excess of 1 Gbps, while the vision of the 1 Tera bps rate corresponds to aggregate capacity of a large number of users served in a metropolitan area. This target calls for a revolutionary step for the techniques to be adopted [2]:

a) WISDOM shall consider new communication systems, based on the suitable transmission, signalling and modulation techniques, to be implemented also in new bands.
b) MIMO and Virtual MIMO links in the mm-wave bands: MIMO and Virtual-MIMO (on both sides of the link) and various types of beam-forming for establishing highly directional links at high frequencies and in fast-fading environments.
c) Use of small cells and virtual cells
    - A virtual cell is a group of small cells synchronized in a way that they all operate in the same channel and are seen by the terminal as a single base station. The key advantage of such a solution, is that mobility signalling is not increased compared to larger cell systems and therefore management overhead and terminal complexity are in the same order of magnitude. At the same time the solution retains the advantages of a small cell system since the short distance between the terminal and the nearest cell allows high bandwidth communication.

Figure 2.6 illustrates the network scenario/architecture for outdoor cellular system with the following listed components [1]:

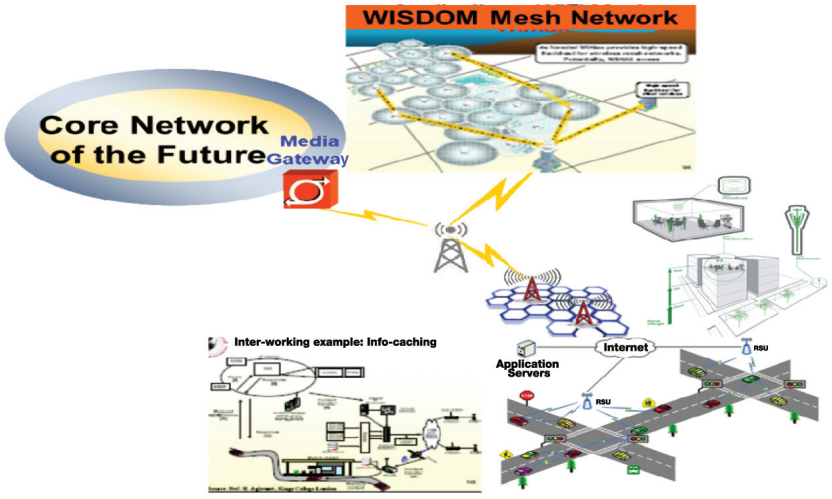

Figure 2.6 Network architecture scenarios for outdoor mobile communications [2].

- WISDOM Base Station and User Equipment: Multi-band, Multi-Radio, MEA Systems
- In mm-wave Communications
- MIMO and Virtual MIMO links in the mm-wave bands. Different network architectures (Multi-hop Mesh, ad-hoc, Wireless/Wireline back-hauling, Intelligent Transport System (ITS)/Vehicular-to-Infrastructure (V2I))
- The concept of CN
- The human-centric paradigm

Figure 2.7 explains the network scenario for next generation cellular networks and it consists of network of radio cells. It is aimed to achieve Wireless Metropolitan Area Network (WMAN). At the WMAN scale, the vision of Tera bps wireless corresponds to aggregate capacity of all wireless users served in a metropolitan area. For example, 400 radio cells in a metropolitan city, each cell serving 10 users, using 250 Mbps each for virtual reality applications: 400 x 10 x 250 Mbps=1 Tera bps [1].

Converged Architecture

WISDOM will help to design a converged architecture and network solution with the goal of enabling ubiquitous terabit wireless connectivity for human-centric mega communications over the network of the future.

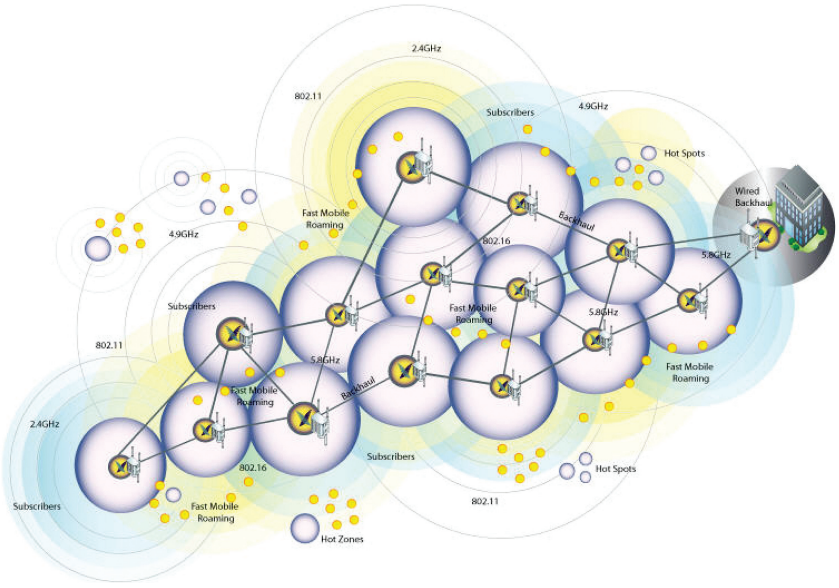

Figure 2.7 Scenario for next generation cellular networks [2].

WISDOM will design and develop wireless/wired interfaces and network protocols in order to integrate the wireless access networks to the fixed infrastructure as well as the core optical part of the Network of the Future. For an optimized wireless/wire line network WISDOM will propose some novel solutions addressing the overall network architecture and the interconnection of the different technology parts of the network with the special focus on interfacing network nodes. This is because these nodes will play the role of edge devices as far as the optical network is concerned and will provide aggregation, traffic shaping and traffic engineering capabilities. For end–to-end user optimization WISDOM will design, developand evaluate novel transport protocols compatible to the wired part (optical fibre) of the network that are able to support the characteristics of both the metro and the core part of the network offering abundant bandwidth in an efficient and cost effective manner. The converged WISDOM architecture will comprise a number of self-organizing/self-healing wireless access networks whose design is based on cognitive and cooperation networking principles. The design of these access networks is based on cognitive networking principles.

The key building blocks of the WISDOM access networks are the WISDOM-node and the WISDOM-station, as shown in Figure 2.8. The

WISDOM-node is envisioned as an intelligent cognitive multi-radio, multi-band, MIMO mobile device capable of operating in a variety of spectrum allocation and interference conditions by selecting cross-layer, cross-network optimized physical and network layer parameters often in collaboration with other radios even if they belong to different co-located networks. The *WISDOM-station* is envisioned as fixed or mobile WISDOM-node that is chartered with the task of providing seamless interconnection between the wire line and wireless parts of the converged architecture [2].

WISDOM node has a vital role in the design of the network algorithms and protocols at the local network and global internetworking levels. Specifically, at the local level, support for cross-layer and cross-network optimization algorithms in autonomous cognitive networks requires an advanced distributed control and management framework. At the global internetworking level, clusters of cognitive networks represent a new category of access networks that need to be interfaced efficiently with the wired network infrastructure both interms of control and data.

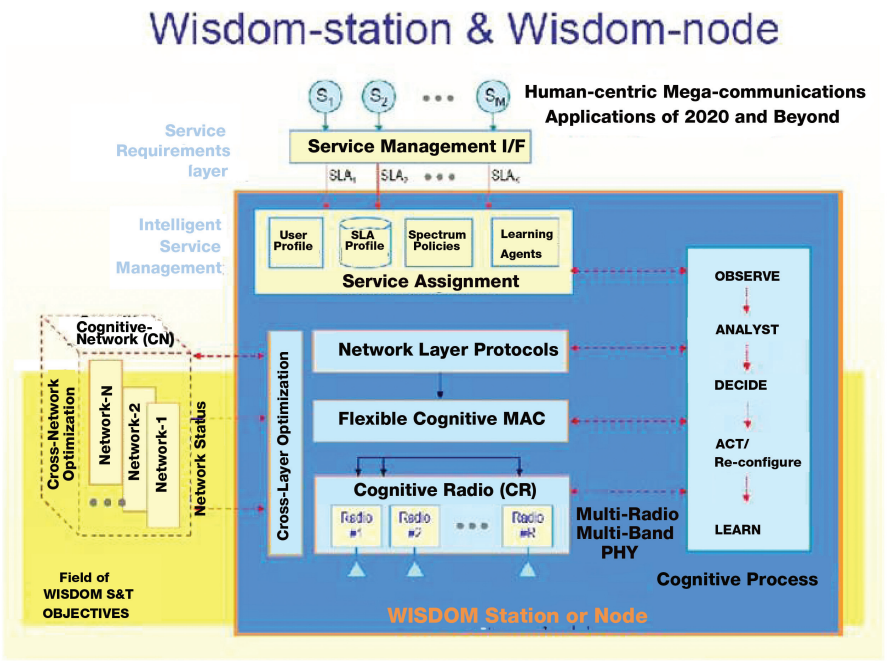

Figure 2.8 WISDOM Node and WISDOM Station [2].

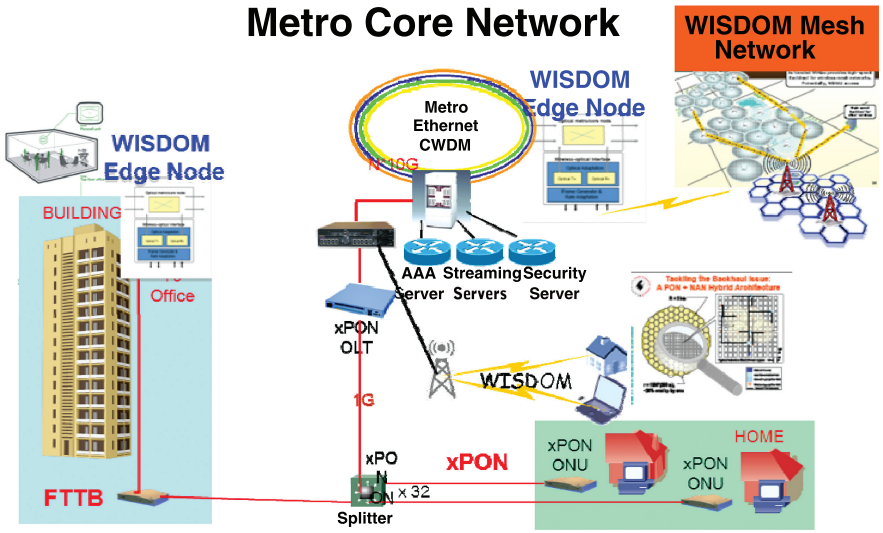

Figure 2.9 End–to-End System Architecture [2]

End-to-End system

The end-to-end system architecture shown in Figure 2.9 consists of the following components [1]:

a) WISDOM Mesh Network
b) WISDOM Edge Node

Metro core network is permutation of WISDOM Mesh Network and WISDOM Edge Node. In this mishmash authentication, authorization and accounting (AAA) streaming security scalable services are included. Security includes robustness, confidentiality and integrity. Robustness provides degree to which a system operates perfectly in all conditions. Confidentiality ensures information is accessible only to those authorized to have access.

2.8 Summary

The aim of the Wireless Innovative System for Dynamically Operating Mega-communications (WISDOM) is to provide terabit communications to the future world. Future networks will feature applications and devices that are highly personalized and humancentric. WISDOM aims to support interest-based service provisioning, where an interest may be based on

user-behaviour or user profile. It will design and develop technologies, systems and network architectures that will enable ubiquitous 1 Tb/s wireless connectivity and communication with coverage extending from C^3W through C^5 (C^3stands for City, country, continent and W stands for World; C^5 represents **C**ommunication, **C**onnectivity, **C**onvergence, **C**ontent, and **C**o-operation) [1]. The important point is that WISDOM combines personal- and cognitive radio-networks towards robust and efficient future networks that will enable a smooth shift from static to dynamic communications, successful businesses that are financially viable and provide secure transfer of information.

References

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