Cognitive Networks for Simultaneous Interaction Spaces

Extended Abstract

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1. INTRODUCTION

Applications define devices and communications networks. From scientific computation to intelligent environments, we witnessed the changes of devices and networks – from mainframes and telecommunication networks to sensor nodes and mobile and wireless networks. It is envisioned that pervasive systems will dominate the future application market [10]. The number of wireless devices, including, laptops, pads, tabs, and sensor nodes will increase to around 100 billion by the year 2025 [5]. The emerging of pervasive systems brings new challenges to network researchers. First, radio frequencies has been over allocated [4]. Little spectrum is left for accommodating new kinds of wireless devices. Second, incompatible radio technologies hinders the interoperability between wireless devices. Third, QoS guarantee becomes an even more difficult goal to achieve when the majority of the network devices have limited resources and data are transported over lossy and time-variant wireless channels. Forth, the increasing complexity of the network and the diversified Internet access technologies impose new challenges for network management. Finally, the original text transportation oriented Internet design is no longer suitable for modern application requirements, such as, abundant IP addresses, security guarantee, QoS guarantee, and wireless and mobility support, etc.

An emerging network, called Cognitive Network (CN), can be a promising solution to the above mentioned problems. A Cognitive Network is a network with a cognitive process that can perceive current network conditions, and then plan, decide, and act on those conditions. The network can learn from these adaptations and use them to make future decisions, all while taking into account end-to-end goals. [11]. First, CRs, which are fundamental elements of a CN, solve the problem of spectrum scarcity by accessing the spacial or temporal spectrum holes opportunistically. Second, SDRs used by CRs are capable of changing working frequencies, modulation methods, and radio waveforms (just to name a few). Two CRs or one CR and a normal wireless device can talk to each other as long as they have overlapping frequencies. This makes interoperability no longer a problem. Third, by switching wireless channels and adapting transmission waveforms, a CN can guarantee a certain level of QoS. Finally, a CN is intended to manage itself autonomously. A Cognitive Engine does all the network management work for human operators. It observes the current network conditions, plans, decides, adapts, and improves its decisions through learning.

The last problem stated above lies in the design of the current Internet. It cannot be solved effectively by only evolving the Internet. A clean slate redesign of the Internet is needed to tackle the problems rooted in the current design.

2. SYSTEM DESIGN

Our network has three planes – a knowledge plane, a control plane, and a data plane. It is impossible to do original designs and implementations for all of them with only one Ph.D. thesis. The task of this Ph.D. work is to design and implement a deployable Cognitive Network for Simultaneous Interaction Spaces. Therefore, some reuse of current work is necessary. We will build a clean interface to integrate the current work and adapt and plenish (e.g., with domain specific protocols) them when necessary. Next, I will present and motivate our design choices.

2.1 Network Topology

The network topology we designed is depicted in Figure 1. Wireless devices communicate with one another via a cognitive radio mesh backbone, which also provides Internet access services.

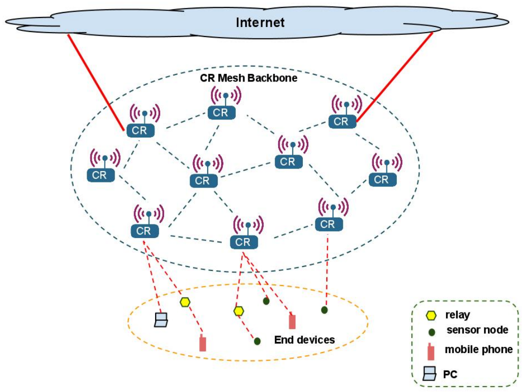

Figure 1: Network topology: a Cognitive Radio mesh network as a backbone

The wireless mesh backbone comprises Cognitive Radios. A CR or an ideal CR is a wireless system with the capabilities of sensing, perception, orientation, planning, making decisions, taking actions, and learning autonomously [8].

CRs, at present, are less efficient compared to dedicated wireless routers, in terms of providing routing services. But our current focuses are adaptability, interoperability, and scalability. We believe efficiency will not be a problem in the future when CRs become a universal platform and are integrated into dedicated wireless routers.

We choose an infrastructure network over an infrastructure-less network, because fixed CR backbone nodes can provide constant Internet access and radio mediator services. Backbone nodes usually have unlimited resources and wider frequency ranges. They can work as mediators to help radios without overlapping frequencies to talk to each other.

In our design, sensor nodes are directly connected to the backbone. This is different from traditional designs where sensor nodes form a network and communicate with outside world through a gateway. Our design eliminates the drawbacks incurred by gateways, such as, single-point-of-failure and throughput bottlenecks. Our topology is cleaner and simpler. Sensor nodes together with other wireless devices all connect to a single backbone. This solves another problem of traditional sensor networks – interferences among multiple geographically co-located sensor networks.

2.2 Network Architecture

As stated previously, a clean slate network architecture compatible with current Internet technologies is the best choice for future applications. A good candidate is RINA – the Recursive InterNetwork Architecture [6]. The core concept of RINA is "networking is InterProcess Communication (IPC)". The communications of a node is managed by IPC facilities. There can be multiple IPC processes within one node, with each of them working on different levels/network-scopes. Lower level IPC processes provide services for higher level ones.

RINA is simpler, more powerful, more scalable and more secure than the Internet today [2]. It makes mobility, multihoming and multi-casting natural results of its design. Private networks are the norm. The problems of security, routing table growth, and IP address scarcity disappear. Middleboxes and layer violation do not exist. Routing is only a local matter [7]. There is no need to define a universal routing protocol that is suitable for all kinds of networks. Consequently, Internet access problems having been frustrating sensor network researchers disappear. Ishakian et al., in [9], show that a routing protocol based on RINA architecture outperforms LISP and MIP in terms of mobility and multi-homing support.

2.3 Cognitive Engine

Since Virginia Tech's CWS group is the pioneer in CE design, and the CROSS [1] project, conducted at VT, is maintaining a reference implementation of their CE, it is reasonable for us to incorporate VT's CE into our system.

2.4 Integrated System View

Figure 2 depicts an overview of our system. The CE part is adapted from [3], and the IPC facility part is adapted from [7].

When an application process wants to communicate with another application process on a different network device,

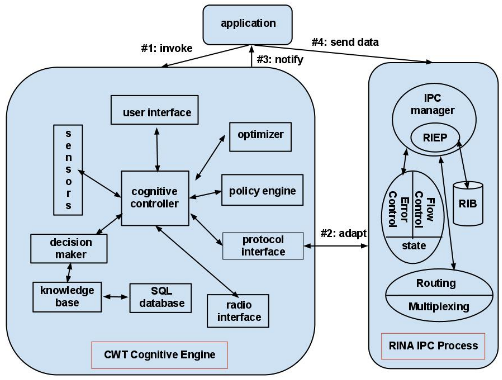

Figure 2: Software architecture for powerful devices

it invokes the CE. The CE analyzes the current network conditions and reconfigures the network to best meet the application's requirements. After reconfiguration, the application is notified and the data is passed to an IPC process (the data and control planes) for transportation. The CE can be implemented on one machine or distributed across multiple machines. The IPC facility implements the RINA architecture.

3. ACKNOWLEDGMENTS

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4. REFERENCES

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