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A Ubiquitous wireless network architecture and its impact on optical networks

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ABSTRACT

Optical networks will change greatly over the next 10 years. This is because, if the current growth rate is maintained, the Internet will have expanded 100–1000 times. Networked wireless appliances, such as radio frequency identification (RFID) tags and wireless sensors, are expected to greatly outnumber PCs. Such exponential changes in network capacity and terminals may lead to the emergence of post-IP networks. This paper introduces a candidate for a post-IP network called the "appliance defined ubiquitous network (ADUN)", which supports niche ubiquitous network applications for affordable implementation. The ADUN will demand optical networks that can transport 10–100 Gbps streams, each of which requires almost the full transmission capacity of one wavelength or a wavelength group. This paper discusses directions for the functional enhancement of optical network architecture, dynamically using wavelengths for grid computing, so as to support the ADUN.

1. Introduction

The Internet has continued to grow rapidly. A task force organized by the Japanese Ministry of Internal Affairs and Communications estimated that Japanese Internet traffic had more than doubled in a year, by measuring the traffic at the Internet Exchange Point in Tokyo in April 2004 [1]. Their most recent report, in February 2007, shows that the Japanese Internet is still growing at a rate of 150% per year. At this rate, the Japanese Internet will be 100–1000 times larger after 10 years. This is true for both the core and access networks. The number of fibers to the home (FTTH) service subscribers will soon exceed 10 million. This Internet growth rate will eventually be matched throughout the world. Such exponential growth will inevitably lead to a huge qualitative change in the network. Optical networks should be able to support both exponential capacity growth and qualitative changes, since they form one of the most basic infrastructures of information and communication technology.

Network architectures have previously been determined by the major terminals for the networks. Telephony networks are designed to provide stable voice communication channels for 3.4 kbps voice streams between telephones by ensuring that the quality of the service meets certain standards. It should be noted that packets are routed between host computers on the Internet, while telephony networks are switched networks. This difference between the characteristics of the two types of network traffic leads to a difference between the two network

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architectures. Therefore, the essential architectural change of the Internet is considered to depend on whether computers remain as the major terminals in the future.

Passive or active radio frequency identification (RFID) tags and wireless sensors are expected to be employed for networking real objects of the real world. If this approach is implemented, such devices will become the major terminals, since the number of real objects is a hundred or a thousand times greater than the number of PCs. Most of the devices are much weaker than PCs in terms of their functions. They will be power-sensitive and will not always operate at high speed. They provide functions for limited purposes. Once they constitute the majority of terminals, the networks, hereafter "ubiquitous wireless networks", will undergo essential changes in terms of architectures.

This paper introduces a ubiquitous wireless network architecture leading to the post-IP network, and discusses its impacts on the optical network architecture supporting both the IP and the post-IP networks with much greater bandwidths than those presently in use. It is often useful for future network design to study extremely high-end applications. As one of such network designs, Section 2 introduces an optical local area network that can transmit Terabit-class bulk data with low latency in a dynamic manner for grid applications with super-computers [2]. Section 3 reviews the history of disruptive network innovations. The review points out that network architectures are determined by terminals or appliances to be networked, and that optical networks should be designed accounting for the possible shift of appliances to be networked in the future. In Sections 4 and 5, active RFID appliances are introduced as the entry and the ultimate appliances for the ubiquitous wireless networks, and the grand challenges for ubiquitous wireless network deployment are discussed and summarized. In Section 6, we introduce an approach to ubiquitous wireless network deployment and show that this approach may lead to a post-IP network. The approach introduces a new architecture, called the appliance defined ubiquitous network (ADUN) [3], where wireless radio spaces are virtually extended over broadband networks to enable affordable implementation of ubiquitous network applications. Broadband streams of 10–100 Gbps are transmitted over the ADUN. In order to employ advanced digital radio signal-processing technologies as far as possible, virtually extended wireless spaces should maintain the relationship between their corresponding real spaces. This paper discusses the new requirements that this will impose on optical networks. These requirements are different from those imposed by grid applications. They indicate the progress direction of the optical network as the basic infrastructure for both the Internet and post-IP networks.

2. Optical network evolution

When developing innovative technologies for network capacity expansion, it is often useful to study the requirements of high-end applications. For example, grid computing for super-computers has the potential to generate extremely large data transmissions. Recent grid applications typically have terabit to petabit data size requirements [4], and each data set should be transmitted within several seconds or several tens of seconds. This section introduces the approach proposed in [2] that is designed to satisfy these requirements by using wavelength groups dynamically. We call optical networks that employ groups of wavelengths dynamically from end to end "lambda access networks."

An optical local area network architecture has been proposed [2], where terabit-class bulk data can be transmitted with low latency in a dynamic manner. Fig. 1 shows an example network configuration. The network consists of parallel optical interfaces, each of which is attached to three components: a super-computer or a visualization server; wavelength-banks, each of which provides required wavelengths to each interface; and an optical switch, which connects an optical interface via optical fibers in the star configuration. It should be noted that the concept must include multiple switching nodes and not be restricted to the star topology. The main characteristics of the network architecture, known as optical virtual concatenation, are (1) the assignment of an arbitrary number of wavelengths to a bulk-data set for transmission according to the latency requirement, and (2) the transmission of a bulk-data set by dividing it into an arbitrary number of blocks and passing the blocks across parallel WDM signals as virtually contiguous data. When a bulk data set arrives at an optical interface, the transmitter requests the establishment of optical channels on multiple wavelengths through the control plane, where the number of wavelengths is derived from the latency requirement. The transmitter divides the bulk-data set into parallel streams, and stores them in electronic buffer-memories until the reservation is complete. If the optical switch finds a group of available wavelengths, it sends a positive command and information about the wavelengths, either to the next optical switch (hop) or to the receiver, through the control plane. If the receiver accepts the positive command and information, it sends back an acknowledgement signal with wavelength group information. The optical switch receives the acknowledgement, transfers this to the transmitter, and then sets up the switch configuration.

The key physical technologies in the above network have been verified in a field demonstration [5]. A successful optical virtual concatenation of 32 km was achieved, where the wavelength group switching was implemented by an 8×8 planar lightwave circuit (PLC) optical switch matrix, and the wavelength group conversion was implemented by a polarization independent waveband converter based on the quasi-phase – matched LiNBO3 (QPM-LN) waveguide.

3. Possible disruptive innovation of ubiquitous wireless networks

3.1. Network architecture dependability on terminals or appliances

We should pay attention to the possibility that the extraordinary expansion of network capacity may lead to a shift in network architectures or, more generally speaking, the ICT platforms. Network architectures have histori-