DWDM Technology and E–Government Initiatives

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INTRODUCTION

The pervasive use of the Internet and unprecedented demand for dependable access to bandwidth-intensive multimedia applications motivate utilization of Dense Wavelength Division Multiplexing (DWDM) as a technological enabler of electronic government (e-government) operations by public agencies. In the public-sector, DWDM increasingly serves as a reliable technology for enhancing citizen access to inter-agency and intra-agency e-government programs, regulations, and policies and providing high-speed connectivity to e-government resources via optical fiber, a medium that transports voice, video, and data signals as light pulses. In addition to provisioning connections to feature-rich applications, DWDM also supports network backbone operations and accommodates bandwidth requirements for e-government interactions that take the form of government-to-government (G2G), government-to-employee (G2E), government-to-citizen (G2C), and government-to-business (G2B) exchanges (Carter & Belanger, 2004).

This chapter delineates the distinctive attributes of DWDM technology and the capabilities of DWDM in providing the capacity necessary for supporting e-government services that are responsive to citizen requirements. Metropolitan area and wider area e-government initiatives that utilize DWDM technology are described. Finally, considerations leading to effective utilization of this technology in supporting public-sector services are explored.

BACKGROUND

DWDM Technical Fundamentals

DWDM optimizes the capacity of a single optical fiber strand by dividing the optical spectrum into numerous non-overlapping lambdas or wavelengths of light to facilitate reliable high-speed transmission of vast numbers of optical signals concurrently with minimal or zero latencies. DWDM enables voice, video, and data transport at the Optical Layer, a sublayer of the Physical Layer or Layer 1 of the seven-layer OSI (Open Systems Interconnection) Reference Model in MAN (metropolitan area network) and WAN (wide area network) environments. In the public-sector, DWDM seamlessly interworks with Asynchronous Transfer Mode (ATM), Synchronous Optical Network/Synchronous Digital Hierarchy (SONET/SDH), Internet Protocol (IP), Gigabit Ethernet, and 10 Gigabit Ethernet broadband technologies.

DWDM Advantages and Limitations

With DWDM, the total amount of information transported is determined by multiplying the capacity of each lambda or wavelength of light by the total number of lambdas available (Littman, 2002). For example, in an 80 lambda DWDM network, 80 times the capacity of each 10 Gbps (gigabits per second) lambda enables transmissions at rates of 800 Gbps via a single optical fiber strand. This rate is doubled to 1.6 Tbps (terabits per second) in an 80 lambda DWDM solution featuring a pair of optical fiber strands.

It is important to note that a DWDM implementation is also subject to operational constraints. Physical barriers to DWDM optical transmission include chromatic dispersion that requires periodic signal regeneration through the use of electrical-to-optical-to-electrical conversion. Moreover, DWDM transmissions are adversely affected by unexpected temperature changes in optical equipment, the optical signal-to-noise ratio (OSNR), and manufacturing flaws in the optical fiber plant. Optical signal attenuation and crosstalk negatively impact high-volume optical throughput as well (Littman, 2002). To counter these constraints, network management systems designed for DWDM implementations monitor network performance, support fault identification and isolation, and enable system restoration resulting from optical fiber cuts and breakdowns in optical devices.

DWDM long-haul backbone networks support terabit transmission rates (Davis, Smolyaninov, & Milner, 2003). However, technical advances in the access network or that portion of the infrastructure between the home or business location and the telecommunications company central office (CO) or the first-mile do not keep pace with DWDM backbone network developments. As a consequence, transmission rates from the DWDM backbone

network via the CO to the customer premise reflect the speed of the first-mile connection.

First-mile technologies including digital subscriber line (DSL) variants such as ADSL2 (asymmetric DSL2) and ADSL2+ employ sophisticated modulation techniques to optimize the transmission capacity of twisted copper pair typically found in the public switched telephone network. ADSL2 supports downstream rates at 18 Mbps (megabits per second) and ADSL2+ enables downstream rates at 24 Mbps over distances that extend to 4 km (kilometers). Increasingly popular, Ethernet in the first-mile over optical fiber broadband passive optical network (BPON) solutions foster downstream rates of 100 Mbps in fiber-to-the home (FTTH) and 1 Gbps in fiber-to-the-business (FTTB) configurations over distances that extend to 10 km (Littman, 2002).

DWDM and CWDM (Coarse WDM)

As with DWDM, CWDM is based on WDM technology and works either independently or in conjunction with DWDM. CWDM utilizes uncooled lasers that require less precise wavelength control and less costly optical components than DWDM. CWDM supports up to 16 lambdas on a single optical fiber strand whereas DWDM enables as many as 80 and potentially more lambdas to achieve terabit and petabit transmission rates.

CWDM technology is primarily used to extend the reach of optical fiber networks in local area BPONs. As with Ethernet BPONs, CWDM BPONs are immune to lightning and other transient forms of electromagnetic interference and feature greater bandwidth and fewer points of failure than first-mile broadband access network technologies such as ADSL2 and ADSL2+. Government agencies providing services in MANs and WANs also employ CWDM/DWDM configurations with an option to implement DWDM upgrades in response to traffic demand (Littman, 2002).

DWDM Standards

The ITU-T (International Telecommunications Union-Telecommunications Sector) approved Recommendations in 2001 for standardization of next-generation DWDM optical transport networks (OTNs) that provision on-demand bandwidth service. Endorsed in 2003, the ITU-T G.959.1 Recommendation describes capabilities of DWDM networks in enabling dependable high-speed transmissions at distances of 40 km and 80 km without signal amplification. In addition to the ITU-T, organizations that promote development of standards for interoperable high-capacity next-generation DWDM configurations include

the European Telecommunications Standards Institute and the Internet Engineering Task Force.

DWDM E-GOVERNMENT INITIATIVES

E-government refers to the use of technology for enabling citizens to conduct online transactions and access government applications and services (Ke & Wei, 2004). In response to citizen demands for a more responsive government, public-sector entities increasingly employ DWDM to support cross-agency network consolidation, integration of fragmented and distributed processes, improvements in the quality of citizen services, and high-speed access to e-government resources and e-collaborative tools via a single interface (Bakry, Al-Bassam, & Alheraish, 2004).

The increase in multimedia traffic resulting from Internet popularity and requirements to ensure network reliability and availability contribute to the use of DWDM technology in e-government initiatives (Stoll, Leisching, Bock, & Richter, 2001). Capabilities of DWDM in enabling e-government services in metropolitan DWDM (MDWDM) networks in municipalities in Canada, Japan, and the U.S. are initially examined in this section. The role of DWDM in facilitating regional and wider area network operations in Canada, the European Union, South Korea, and the U.S. is then explored.

MDWDM Networks

Canada

Multiple factors including the pervasiveness of Web applications and demand for seamless high-speed access to interactive e-government services contribute to the use of MDWDM technology in Canada as a platform for supporting municipal e-government initiatives (Grobe, Wiegand, & McCall, 2002). For example, the City of Ottawa (2003) in the Province of Ontario administers Telecom Ottawa, a municipal public utility that provides MDWDM operations to support civic projects that include the City of Ottawa's Smart Central initiative. Sponsored by the Ottawa Center for Research and Innovation, this MDWDM-based e-government initiative interlinks public-sector agencies, research laboratories, local hospitals, businesses, schools, and post-secondary institutions and provides fast and dependable access to e-healthcare, e-learning, and e-business applications and national, regional, and municipal services. The City of Ottawa also participates in the Ottawa Rural Communities Network

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