WI-MAX THROUGH ROF: A THEORETICAL STUDY AND SURVEY

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ABSTRACT

Wireless technology has introduced high speed internet accessibility through wireless broadband. Radio over fiber; the integration of microwave and optical networks is the potential solution for reducing cost in terms of equipment, running finance and capacity enhancement in wireless communication systems. IEEE 802.16 Wi-MAX has emerged as a revolutionary wireless broadband access technique over past few years. This paper summarizes the advantages of incorporating RoF as a backhaul technology for providing Wi-MAX services. Various performance measures like data rate, attenuation, and dispersion errors have been studied and discussed in the paper for different types of fiber. Various features of Wi-MAX services offered by Bharat Sanchar Nigam Ltd. have also been summarized to develop better understanding and know practical implementation of the technique.

Key words: Radio over Fiber (ROF), Wi-MAX, Dispersion, Fiber Nonlinearities.

I. INTRODUCTION

As per the increasing demand for broadband services which leads to ever-growing data traffic volumes over these services. In addition to the high-speed, symmetric, and guaranteed bandwidth demands for future video services, the next-generation access networks are driving the needs for the convergence of wired and wireless services. RoF technology, the integration of microwave and optical networks as shown in figure 1, is an interesting and promising solution for increasing capacity and mobility as well as decreasing costs in the access network.

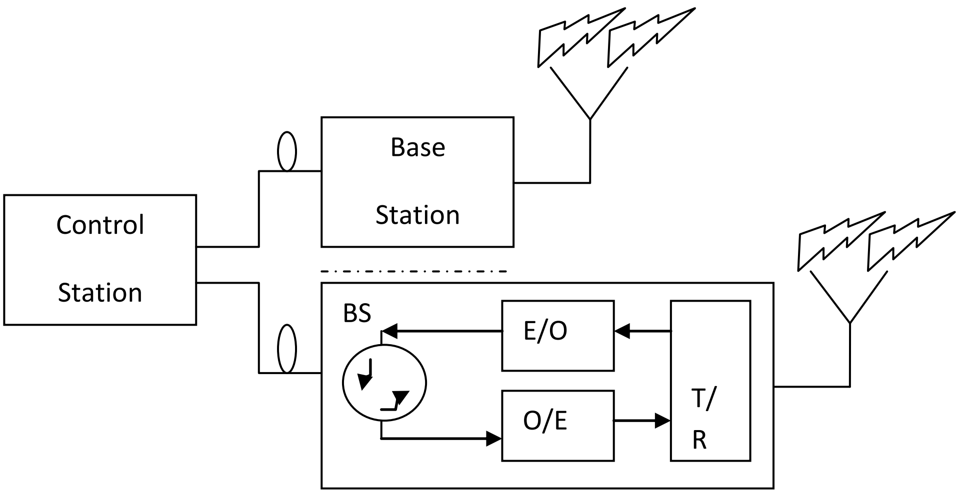

Figure1: General RoF System

The concept of RoF is to transport information over optical fiber by modulating the light with the radio signal. The modulation can be done directly with the radio signal or at an intermediate frequency. RoF technique has the potentiality to the backbone of the wireless access network. Such architecture can give several advantages, such as reduced complexity at the antenna site, radio carriers can be allocated dynamically to the different antenna sites , transparency and scalability [1]. To provide integrated broadband services, these systems will need to offer data transmission capacities well beyond the present-day standards of wireless systems. Wireless LAN offering up to 54 Mbps and operating at carrier frequencies around 2.4 and 5 GHz, and 3G mobile networks offering up to 2 Mbps and operating around 2 GHz, are some of today's main wireless standards. Optical wireless networking connectivity can typically be achieved using Radio Frequency (RF) or optical wireless approaches at the physical level. The RF spectrum is congested, and the provision of broadband services in new bands is increasingly more difficult. Optical wireless networking offers a vast unregulated bandwidth that can be exploited by mobile terminals within an indoor environment to set up high speed multimedia services. Optical signal transmission and detection offers immunity from fading and security at the physical level where the optical signal is typically contained within the indoor communication environment. The same communication equipment and wavelengths can be reused in other parts of a building, thus offering wavelength diversity [2].

II. ADVANTAGES

Due to availability of both wired and wireless facilities, RoF system offers following advantages:

(1) Low Attenuation Loss- Commercially available standard single mode fiber (SMFs) made from glass (silica) have attenuation losses below 0.2dB/km and 0.5dB/km

(2) Large Bandwidth- There are three main transmission windows, which offer low attenuation, namely the 850 nm, 1310 nm and 1550 nm wavelengths. For a standard SMF optical fiber, the combined bandwidth of the three windows is in the excess of 50 THz.

(3) Immunity to Radio Frequency Interference- This is so because signals are transmitted in the form of light through the fiber. Because of this immunity, fiber cables are preferred even for short connections at mm-waves.

(4) Reduced Power Consumption.

(5) Dynamic Resource Allocation- Since the switching, modulation, and other RF functions are performed at a centralized station, it is possible to allocate capacity dynamically.

(6) Millimeter Waves- Millimeter waves offer several benefits. Firstly, they provide high bandwidth due to the high frequency carriers. Secondly, due to high RF propagation losses in free space, the propagation distances of mm-waves are severely limited. This allows for well-defined small radio sizes (microcells and picocells), where considerable frequency reuse becomes possible so that services can be delivered simultaneously to a larger number of subscribers.

III. IEEE 802.16 WiMAX

Wi-MAX is one of the most widely used broadband technologies now a days in the world. WiMAX system delivers broadband services in an economical way both to enterprise and residential customers. [3] WiMAX an alternative to wire technologies like DSL, T1/E1, cable modems is a wireless version based on Ethernet standards. More, WiMAX is an industry organization formed by leading equipment and component companies for compatibility and interoperability of wireless broadband access system confirms to IEEE 802.16. WiMAX operates similar to Wi-Fi but it provides greater distance coverage, high speed then Wi-Fi and can accommodate a large no of users. WiMAX can provide its services in an area difficult for wired connections to reach and also overcome the limitations the wired networks [4]. WiMAX formed in April 2001, operates in the frequency range of 10-66 GHz under IEEE 802.16 specifications, supports up to 40Mbps.

IV. FIBER NONLINEARITIES AND DISPERSION

Fiber Nonlinearities [5]: The optical nonlinearities considered are those that can give rise to gain or amplification, the conversion between wavelengths, the generation of new wavelengths or frequencies, the control of the temporal and spectral shape of pulses, and switching. They result from the interaction between several optical fields simultaneously present in the fiber and may also involve acoustic waves or molecular vibrations. Fiber nonlinearities can be distinguished in two different types

I) The nonlinearities that arise from scattering [Stimulated Brillouin Scattering (SBS) and Stimulated Raman Scattering (SRS).

II) The nonlinearities that arise from optically induced changes in the refractive index, and result either in phase modulation [Self-phase Modulation (SPM) and Cross phase Modulation (XPM)] or in the mixing of several waves and the generation of new frequencies [modulation instability (MI) and parametric processes, such as four wave mixing (FWM).

Kerr Effect: The refractive index n of many optical materials has a weak dependence on optical intensity.

$$n=n_0+n_2I$$

n_0= ordinary refractive index of the material

n_2=nonlinear index coefficient

So, this nonlinearity in the refractive index is known as Kerr nonlinearity. This nonlinearity produces a carrier induced phase modulation of the propagating signal, which is called Kerr effect.

Dispersion Effects [6]: Dispersion is a phenomenon of spreading of light pulse as it travels down the fiber. As a result of this Inter Symbol Interference (ISI) occurs, hence performance is adversely affected.

1) Intermodal Dispersion: It appears only in multimode fibers. It is a result of each mode having a different value of group velocity at a single frequency. This mechanism can be eliminated by single mode operation, but is important in multimode fibers.

2) Intramodal Dispersion: This effect takes place within a single mode. This spreading arises from the finite spectral emission width of an optical source.

(a) Material Dispersion: It arises due to the variations of the refractive index of the material as a function of wavelength[7]. Material dispersion is also referred as chromatic dispersion.

(b) Waveguide dispersion: It causes pulse spreading because only part of the optical power propagation along a fiber is confined to core. A fraction of the light power propagating in the cladding travels faster than the light confined to the core since the index is lower in the cladding. Waveguide dispersion can be ignored in multimode fiber but its effect is significant in single mode fiber.

V. SURVEY:-WI-MAX THROUGH ROF

In India, WebSky created a joint venture with World-Wide Wireless India (WWWI) to design, build and run a network that could address 75m people. WebSky started providing the funding and constructed the system while WWWI contributed its licensed frequencies in 3.5GHz spectrum, which covered nine large cities, including Mumbai (Bombay), Delhi, Calcutta, Chennai (Madras), Bangalore and Hyderabad. The first build-out occured in the city of Ludhiana, in Punjab.

Also in India, telecom giant **Bharat Sanchar Nigam Limited (BSNL)** announced plans to roll out Wi-MAX services in 10 major cities, including Hyderabad, Pune, Ahemdabad and Bangalore in 2005. The installation and commissioning of Wi-MAX certified equipment of BSNL is currently available across many cities in India. On trial basis BSNL deployed Cambridge Broadband's Vectastar Equipment in Gurgoan near Delhi. Its consumer premises equipments (CPEs) are multi frequency and multi sector. Vectastar's technology product is used for both access and transmission with the network combining IP based access services with the backhaul of traffic from GSM, 3G, and Wi-MAX base stations.

French telecom major Alcatel joined hands in an agreement with the **Centre for Development of Telematics (CDoT)** to set up a global research and development centre in India for broadband wireless products. Alcatel believes that broadband wireless and particularly Wi-MAX is appropriate technology for India keeping in mind the requirements of the rural sector.

5.1 Types of Optical fiber Deployed

The International Telecommunication Union (ITU-T), which is a global standardization body for telecommunication systems and vendors, has standardized various fiber types. These include the Non dispersion-shifted fiber (G.652), dispersion-shifted fiber (G.653), 1550-nm loss-minimized fiber (G.654), and NZDSF (G.655).

1. Non dispersion-Shifted Fiber (ITU-T G.652)- The ITU-T G.652 fiber is also known as standard SMF and is the most commonly deployed fiber[8]. It has a zero-dispersion wavelength at 1310 nm and can also operate in the 1550-nm band, but it is not optimized for this region. The typical chromatic dispersion at 1550 nm is high at 17 ps/nm-km. Dispersion compensation must be employed for high-bit-rate applications. The attenuation parameter for G.652 fiber is typically 0.2 dB/km at 1550 nm, and the PMD parameter is less than 0.1 ps/ km.

2. Low Water Peak Nondispersion-Shifted Fiber (ITU-T G.652.C)-The legacy ITU-T G.652 standard SMFs are not optimized for WDM applications due to the high attenuation around the water peak region. ITU G.652.C-compliant fibers offer extremely low attenuation around the OH peaks. The G.652.C fiber is optimized for networks where transmission occurs across a broad range of wavelengths from 1285 nm to 1625 nm. Although G.652.C-compliant fibers offer excellent capabilities for shorter, unamplified metro and access networks, they do not fully address the needs for 1550-nm transmission. The attenuation parameter for G.652 fiber is typically 0.2 dB/km at 1550 nm, and the PMD parameter is less than 0.1 ps/ km.

Based on optical power loss of fiber, spectrum ranges have been characterized for compatibility purposes with light sources, receivers, and optical components, including the fiber. Thus, the low-loss spectrum for single-mode fiber has been subdivided into smaller regions [9]. The S-band (short-wavelength or second window) is defined in the range 1280-1350 nm. The C-band (conventional or third window) is defined in the range 1528-1565 nm. This is also subdivided into the "blue band" (1528-1545 nm) and the "red band" (1545-1561 nm). The L-band (long-wavelength or fourth window) is defined in the range of 1561-1620 nm. The "new band" (or fifth window) is defined in the range of 1350-1450 nm. The S- and C-band ranges have found applications in WDM metropolitan networks. The C- and L-band ranges have found applications in ultra-high-speed (10-40 Gb/s) WDM networks [10]. The L-band takes advantage of the dispersion compensating fiber that effectively extends the C-band range to 1600 nm, thus doubling the number of wavelengths better suited to DWDM applications.

Sr. No.	Type	Wavelength Coverage	Dispersion	Application
1	6.652A	1310 nm , 1550 nm	0.5ps/km-nm	Supports 10Gbps upto 40 kms
2	6.652B	1310nm , 1550 nm, 1625 nm	0.2ps/km-nm	Supports 10Gbps upto 40 kms, attenuation is max at 1625 nm
3	6.652C	1310 nm , 1550 nm	0.5ps/km-nm	Similar to 6.652A, suitable for CWDM
4	6.652D	1310nm , 1550 nm, 1625 nm	0.2ps/km-nm	Similar to 6.652B, suitable for CWDM

ITU_T G.652 defines the different standards of single-mode optical fibre cable and its characteristics. This recommendation describes the geometrical and transmission attributes of single-mode optical fibre and cable with chromatic dispersion and cut-off wavelength that are not shifted from the 1310 nm wavelength region [11]. ITU_T G.653 describes the characteristics of a dispersion shifted single mode optical fibre cable. ITU_T G.654 describes the geometrical, mechanical and transmission attributes of a single mode optical fibre and cable which has the zero-dispersion wavelength around 1300 nm wavelength, and which is loss-minimized and cut-off wavelength shifted at around the 1550 nm wavelength region [12]. ITU_T G.655 describes the geometrical, mechanical, and transmission attributes of a single-mode optical fibre which has the absolute value of the chromatic dispersion coefficient greater than some non-zero value throughout the wavelength range from 1530 nm to 1565 nm [13]. This dispersion reduces the growth of non-linear effects which are particularly deleterious in dense wavelength division multiplexing systems. ITU-T G.656 describes the geometrical, mechanical, and transmission attributes of a single-mode optical fibre which has the positive value of the chromatic dispersion coefficient greater than some non zero value throughout the wavelength range of anticipated use 1460-1625 nm. This dispersion reduces the growth of non-linear effects which are particularly deleterious in dense wavelength division multiplexing systems. ITU_T G.657 to support this optimization by recommending strongly improved bending performance compared with the existing ITU-T G.652 single-mode fibre and cables. This is done by means of two categories of single-mode fibres, one of which, category A, is fully compliant with the ITU-T G.652 single mode fibres and can be deployed throughout the access network [14]. The other, category B, is not necessarily compliant with recommendation ITU-T G.652 but is capable of low values of macro bending losses at very low bend radii and is intended for use inside buildings or near buildings. Attenuation Summary for various kinds of fibers-

Sr. No.	Fiber Type	Bending Radius	Attenuation
1	G 652	37.5 mm	0.5 dB
2	G 657 A1	15 mm	0.25 dB
3	G 657 A2	15 mm	0.03 dB
4	G 657 B2	15 mm	0.03 dB
5	G 657 B3	10 mm	0.03 dB

Wi-MAX service provided by BSNL offers following features and specifications-

Standard Range	50 kms
Shared data rate(Wi-MAX) (Wi-MAX release 2)	70 Mbps 365 Mbps for Mobile user, 1Gbps for fixed user
Peak downlink rate	365 Mbps
Peak Uplink rate	376 Mbps
Standard Cell coverage	8,000 square km
Frequency Band used (non line of sight) (Line of sight)	2 GHz to 11 GHz 10GHz to 66 GHz (both licensed and unlicensed)
Modulation formats	OFDM/OFDMA,QPSK, 16 QAM, Scalable OFDMA
Protocols followed	Logical Link Controller(standardized by IEEE 802.2) MAC (Media Access Control) layer that supports multiple physical layer
Peak Data Rate	75 Mbps(20 Mhz channel),18 Mbps(5 Mhz channel)
Standard antenna type	4*4 MIMO antenna
No of Sectors	3
Traffic engaged peak %	70 %

No. of T1 lines(1.544Mbps)	14
Average User Throughput	1-3 Mbps
Range Outdoor (Avg Cell)	2–10 kms
Channel BW	Scalable 1.5–20MHz
High end services offered	Real time multimedia and Voice over IP
Mobility Limit	Max of 60 km/h to maintain optimum throughput performance
Interference Source	2-3 GHz Band, only in non line of sight (Majorly Microwave Ovens)
Connectivity efficiency	Approx 60 business with T1-type connectivity and hundreds of homes with DSL-type connectivity

VI. APPLICATIONS

RoF is used in many areas such as following

(1) Cellular Networks
(2) Satellite Communications
(3) Video Distribution Systems
(4) Mobile Broadband Services
(5) Wireless LANs
(6) Vehicle Communication and Control

VII. CONCLUSION

In this paper we have discussed the role of RoF network as the backhaul concept for Wi-MAX service. The presented study helps to develop a better understanding of RoF technology. It is observed that BSNL make use of Non dispersion shifted fiber for transportation of radio signals. Though the losses occurring are very low as compared to dedicated wireless channel, yet performance can be improved by using dispersion compensated fiber. Quality of service will be enhanced once dispersion compensated fibers are installed for the purpose.

ACKNOWLEDGEMENT:- The data for the survey was collected from BSNL Advance level Telecom Training Centre(ALTTC),Ghaziabad.

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