Abstract: This paper consists of two parts: I. Introduction of Radio of Fiber technology & methodology II. Quality parameter & Challenges for Implementation. Wireless communication was one of the paramount ways in term of high bandwidth data communication. Technology like microwave, wireless, optical communication & their combination are used and have improved the performance of the communication. Radio over Fiber technology (RoF), an integration of microwave and optical communication, is an essential technology for the provision of unmetered access to broadband wireless communications.

Keywords: RoF, Subcarrier Multiplexing, Optical Frequency Multiplexing, Wavelength Division Multiplexing, Quality Parameter.

1. INTRODUCTION

Nowadays, there is an increasing demand for broadband services which leads to ever-growing data traffic volumes over these services. It is estimated that approximately 50% of the revenues of large telephone companies will be based on video services by 2010 [1]. 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. Radio-over-Fiber Technology, the integration of microwave and optical networks (shown in figure 1) is a potential solution for increasing capacity and mobility as well as decreasing costs in the access network, by RoF [2]. The concept of RoF means to transport information over optical fiber by modulating the light with the radio signal. This 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, and Transparency and scalability [3].

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. IEEE802.16 or WiMAX is another recent standard aiming to bridge the last mile through mobile and fixed wireless access to the end user at frequencies between 2 and 66 GHz. The need for increased capacity per unit area leads to higher operating frequencies (above 6 GHz) and smaller radio cells, especially in indoor applications where the high operating frequencies encounter tremendously high losses through the building walls. To reduce the system installation and maintenance cost of such systems, it is imperative to make the radio antenna units as simple as possible [4].

2. ADVANTAGES

The radio over fiber technology has more than a few advantages over the conventional optical communication system: (i) Low Attenuation Loss, (ii) Large Bandwidth: RoF technology is used to increase optical fiber bandwidth utilization. (iii) Immunity to Radio Frequency Interference: EMI is a very attractive property of RoF technology, especially for microwave transmission. (iv) Easy Installation and Maintenance: In RoF systems, complex and expensive equipments are kept at the head end, thereby making the Remote Antenna Unit (RAUs) simpler. (v) Reduced Power Consumption: Reduced power consumption at the RAU (vi) Multi-Operator and Multi-Service Operation: RoF distribution system can be made signal-format transparent. (vii) Dynamic Resource
Allocation: In a RoF distribution system for GSM traffic, more capacity can be allocated to a certain area during the peak times and then reallocated to other areas when off-peak. [5]

4 METHODOLOGY

4.1 Subcarrier Multiplexing

Optical subcarrier multiplexing (SCM) is a scheme where multiple signals are multiplexed in the radiofrequency (RF) domain and transmitted by a single wavelength. A significant advantage of SCM is that microwave devices are more mature than optical devices; the stability of a microwave oscillator and the frequency selectivity of a microwave filter are much better than their optical counterparts. In addition, the low phase noise of RF oscillators make coherent detection in the RF domain easier than optical coherent detection and advanced modulation formats can be applied easily. A popular application of SCM technology in fiber optic systems is analog cable television. [6]

In an SCM optical system there are N subcarrier channels. The output electrical field from modulator is

\[ E_{o} = \frac{E_{i}}{2} \left[ \cos(\omega_{c} t + \frac{2\pi}{\Omega} \sum_{k=1}^{N} \alpha_{k} \sin\Omega_{k} \tau) - \sin(\omega_{c} t + \frac{2\pi}{\Omega} \sum_{k=1}^{N} \alpha_{k} \cos\Omega_{k} \tau) \right] \]

\[ = \frac{E_{i}}{2} \left[ \cos(\omega_{c} t + \frac{2\pi}{\Omega} \sum_{k=1}^{N} \alpha_{k} \sin\Omega_{k} \tau) \right] + \frac{E_{i}}{2} \left[ \sin(\omega_{c} t + \frac{2\pi}{\Omega} \sum_{k=1}^{N} \alpha_{k} \cos\Omega_{k} \tau) \right] \]

(2)

where \( E_{i} \) = the normalized digital signal at the kth subcarrier channel, \( \omega_{c} \) = the carrier frequency, \( \Omega_{k} \) = the RF is the subcarrier frequency of the kth channel

It should be pointed out that the receiver sensitivity presented so far did not include signal waveform distortion and inter-channel crosstalk. Signal waveform distortion may be introduced by non ideal transfer function of RF circuitry and optical modulator, chromatic dispersion, self-phase modulation (SPM), and PMD. [7]

3.1 Wavelength Division Multiplexing

WDM are passive devices that combine light signals with different wavelengths, coming from different fibers, onto a single fiber. They include dense wavelength division multiplexers (DWDM), devices that use optical (analog) multiplexing techniques to increase the carrying capacity of fiber networks beyond levels that can be accomplished via time division multiplexing (TDM). The use of WDM for the distribution of RoF signals as illustrated in figure 4, has gained importance recently. WDM enables the efficient exploitation of the fiber network’s bandwidth. These systems can achieve capacities over 1 Tb/s over a single fiber. At the same time, bit rates on a single channel have risen to 10 Gb/s and systems operating at 40 Gb/s channel rates are becoming commercially available. The channel spacing in WDM can be decreased to 50 GHz or even to 25 GHz and thus, it is possible to use hundreds of channels. However, if the channel spacing is dropped to 50 GHz instead of 100 GHz, it will become much harder to upgrade the systems to operate at 40 Gb/s due to the nonlinear effects. [8]

3.3 By Using Optical Frequency Multiplexing: It is a flexible and cost-effective RoF technique that enables multiple functionalities required for the support of wireless access systems. Increased cell capacity allocation, multi-standard support, remote LO delivery and in-band control channel for dynamic radio link adaptation and remote antenna controlling can be provided with a single laser source and low frequency electronics at the CS. Additionally, RoF distribution antenna systems based on OFM can be smoothly merged with broadband access optical networks like WDM-PON, allowing a flexible convergence of optical fiber’s high
capacity and wireless access flexibility. RoF distribution antenna systems in which radio signals are generated at a remote central station (CS) and distributed transparently to several simplified antenna stations (AS) via optical fiber. The main goal of these RoF systems is to reduce infrastructure cost and to overcome the capacity bottleneck in wireless access networks, allowing at the same time a flexible merging with conventional optical access networks. Thus, in order to design a reliable RoF-based access infrastructure, RoF techniques must (a) be capable of generating the microwave signals and (b) allowing a reliable microwave signals transmission over the optical link. The Optical Frequency Multiplication method satisfies these two main requirements by generating the microwave signals with a single laser source and low frequency [8]. Among many other RoF techniques, the Optical Frequency Multiplication principle proposed in is a cost-effective and dispersion-tolerant method to optically generate microwave frequencies and deliver wireless signals to a remote AS.

Where there are S splitters each with loss $L_{opt}$ [10].

4.2 Scattering: One of the most severe nonlinear impairments is stimulated Brillouin scattering (SBS). If the input power into a fiber reaches a critical value known as the SBS threshold (SBST), both the amount of backscattered optical power and generated noise quickly increase with the input power. Therefore, SBS imposes limitations on the amount of optical power that can be launched into the fiber without degrading the signal quality. Recently, there have been investigations on PON systems for radio signal distribution that target applications like 3G cellular and WiMax service distribution, with SBS being the key limiting factor to stimulated Brillouin scattering in radio-over-fiber transmission can be strongly suppressed with the proper choice of a segmented single-mode optical fiber.[11]

4.3 Dispersion: RoF that builds broadband wireless and wired connectivity has become a promising application area for analog optical links. As in this frequency band employed moving to the microwave and millimeter-wave bands, the performance will be distinctly deteriorated by the chromatic distance especially for extended distance. Chromatic dispersion compensation scheme using parallel electro-optic phase and intensity modulators is suitable for long-reach radio-over-fiber links. By properly adjusting the optical power and the time delay between the two modulated signals, the power fading aroused by the dispersion adequately compensated over a wide operating bandwidth of 0–18 GHz over a 34-km single-mode fiber. Optical Fiber is optimized for less chromatic Dispersion so that pulse spreading is kept minimum and then used in the proposed system. [11]

4.4 Bit Error Rate: BER may be affected by transmission channel noise, interference, distortion, bit synchronization problems, attenuation, wireless multipath fading. The BER may be improved by choosing strong signal strength or choosing a slow and robust modulation scheme. From the various studies it shows that the BER for a multimode fiber, the bit rate is more. As the length of the fiber increases the pulse broadening increases and hence decreases the bit rate. Analog ROF and digital ROF links are compared and it can be concluded that BER of Digital link is less as compare to Analog link and hence has superior performance.BER of BPSK is seen to be less than QPSK and 16 QAM in Analog as well as Digital Link. BPSK stands out for its BER even though it is slightly higher than that of 16 QAM, but spectral efficiency 16 QAM is better choice for Digital Link. Digital Radio over Fiber shows improved performance over Analog link. Greater the data symbol modulation the more is the spectrum efficiency but less is the system robustness.

4. QUALITY PARAMETER

4.1 Attenuation: Attenuation of optical signal is an important consideration in the design of optical communication system. Single mode fiber is very suitable for radio over fiber, subsequently the fiber dispersion is not much countable for low frequencies (10GHz) up to several tens of kilometer. Attenuation is a parameter which is dependent on wavelength. Modern fibers offer as low as 0.2 dB/km loss at 1.55 µm. The optical losses (OL) including fiber attenuation and connector losses and splices loss. It can be calculated for an optical link:

$$OL = 2(NL_c + ML_{sp} + uL_f) \ dB$$

(3)

Where $NL_c$ is the connector loss with N connectors; $ML_{sp}$ is the splicing loss with M splices, and $u$ is the fiber attenuation in dB/km. The OL is very large with every time the power split can be computed as follows:

$$OL = 2(NL_c + ML_{sp} + SL_{split} + nL_f) \ dB$$

(4)
4.5 Carrier to Noise Ratio: In ROF networks Mach–Zehnder (MZ) modulators and optical amplifiers are under consideration for a variety of applications, including antenna remoting. In these links, fiber amplifiers are used to increase the RF gain and dynamic range, and improve the noise figure. Modulator bias control in narrowband links can also be used to increase the CNR and the dynamic range. Dynamic range is improved because the bias variations do not increase the odd-order nonlinearities, which are the only ones affecting narrowband signals such as those used in 802.11a/g systems. In such a link, because the CNR improvement is maximum, if link CNR is limited by laser intensity noise or by saturation of the detector, the optical power over the fiber can be high enough to excite nonlinear effects including stimulated Brillouin scattering (SBS). SBS is a serious impairment for signals with narrow optical spectrum; it limits the power that can be transmitted on a single-mode fiber. Optical carrier by controlling the modulator bias can lead to simultaneous optimization of RF gain and suppression of SBS-induced noise. This translates into improvement of the CNR, even for SBS noise limited links, without the complexity of an additional phase modulation. [14]

5 CHALLENGES FOR ROF

Today, RoF has been performed in several recess markets such as the provision of in-building mobile and wireless access systems (distribution of 3G mobile signals or WiFi coverage) or antenna remoting in satellite communication systems. To increase the penetration of RoF in the network several challenges have to be addressed.

(I) The addressing system for current access and in house network evolution which tend to use one single protocol to cumulative and convey the digital data of the different services. This inclination is dissimilar to the use of RoF in the network as, in this case, different protocols are used in parallel and the services are transported transparently on their native protocols as much as possible. On the other hand, an all-IP network evolution may not be entirely desirable as the prioritization of traffic to respond to the increasing services diversity will be extremely difficult to realize. This is being reinforced by the rapidly evolving situation where there is a constant introduction of new services, interfaces and standards each requiring their own specific quality of service.

(II) RoF in access networks come from the necessary mutualisation of the optical infrastructure between the different network types which may have different evolutions. A scenario for using RoF over current Access Networks architectures must be defined but, on the top of this, a scenario for the introduction of RoF over Metro-Access networks must be prepared. The challenge is then to demonstrate the cost savings that will be realized today by using RoF to deploy Mobile and Wireless access over current optical infrastructures.

(III) The lack of standardization for RoF. Some very preliminary work has started to establish and maintain the standard specifying measurement methods for microwave and millimeter-wave to photonic converter, which are used in RoF communication systems. At present, the techniques and architectures used in RoF are very diverse and the adequate solutions must be identified collegially between the different actors in this sector (operators, system suppliers and component manufacturers) in order to push for the most adapted solutions and increase the deployment opportunities. [2]

6 CONCLUSION

In this paper we have studied different techniques for implementation of RoF technology. The comparison of SCM, WDM & OFM is summarized in table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SCM</th>
<th>WDM</th>
<th>OFM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attenuation</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Scattering</td>
<td>SBS</td>
<td>SBS &amp; FWM</td>
<td>SBS</td>
</tr>
<tr>
<td>Dispersion</td>
<td>Chromatic &amp; PMD</td>
<td>Chromatic</td>
<td>Chromatic</td>
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<tr>
<td>BER</td>
<td>Less</td>
<td>More</td>
<td>More</td>
</tr>
<tr>
<td>CNR</td>
<td>Less</td>
<td>More</td>
<td>More</td>
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We conclude in this paper that RoF is a flexible and cost-effective technique that enables multiple functionalities required for the support of wireless access systems. Assistance of RoF technique is reducing the attenuation, dispersion, scattering, can improve bit error rate and bandwidth. Additionally, RoF techniques are smoothly merged with broadband access optical networks like WDM, SCM & OFM (shown in fig.6&7) allowing a flexible convergence of optical fiber’s high capacity and wireless access flexibility.

![Figure 6: Proposed Model for SCM-WDM RoF technique](image)

![Figure 7: Proposed Model for OFM-WDM RoF technique](image)
REFERENCES


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