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Radio over Fiber Technology

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Abstract— Radio-over-fiber (RoF) is an integration of microwave and optical networks for wireless access. It is a promising technology competent to provide simple antenna front ends, greater wireless access coverage and capacity. RoF system has been dependant on well established technology for base band signals, based on direct detection and intensity modulated links, enable to provide implementation of very low cost. This baseband optical communication with digital signals processing allows advanced modulation formats to be used. The ample advantages of using an optical fiber such as its light weight, less loss, larger bandwidth, tiny size and low cost of cable makes it most suitable for transporting radio signals to antenna sites efficiently, situated remotely in a wireless network.

Index Terms— Centralized station, Fiber optic links, IF-over-Fiber, Low-attenuation, Microwave signals, Optical frequency Multiplexing, RF-over-fiber, Radio Frequency amplification, Sub-carrier Multiplexing, Wavelength Division Multiplexing.

1 INTRODUCTION

The network structure of RoF consists of a Centralized station (CS) which performs modulation, demodulation, medium access control (MAC) coding, routing and other processing's. The Centralized Station is connected to several BSs through a fibre optic.

The most important task of BS is the transformation of optical signal into wireless signals and vice versa [2]. It also performs RF amplification. For the distribution of Radio Frequency signals between the Base Station and Centralized station, highly linear fibre optic links are used [4]. Moreover, this centralized configuration can allow the delicate equipments to be kept in a much safer environment. The spreading of radio signals can be classified into wave modulated mm optic signals "RF over fibre" or lower frequency sub carriers "IF over fibre". The ample advantage of RF over fibre is that the design of BS is much simplified. However, the distance of transmission can be limited severely, if the BS is susceptible to fibre chromatic dispersion. When it comes to Intermediate frequency signals, it is not very susceptible to fibre chromatic dispersion, additionally it requires and electronic hardware like a local oscillator for frequency up and frequency down inversion. [1]

2 MOTIVATION

2.1 Insenstivity to Electromagnetic Radiation

RoF was first implemented for a cordless telephone service in 1990. The insensitivity of fibre optic cables to electromagnetic radiation is a major benefit in their implementation as the backbone of a wireless network. A copper coaxial cable has previously been the traditional link between the radio base station (RBS) and the antenna. Using an optical fibre cable instead, makes the design of new sites, as well as the physical deployment of the hardware much easier.

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The Lower power consumption, lower power radiated electromagnetic wave, fibre low attenuation and less loss reduce the maintenance cost. Due to the simple structure of BS, it is highly reliable and system maintenance has become simple. Coverage can be provided by Radio over fibre systems in those areas where direct reception is less effective, like huge buildings or basements. [2]

2.2 Indoor and Outdoor Enviroments

In indoor environments, because of the electromagnetic properties, the em field is restricted by the walls. In outdoor environments, especially at frequencies around 60 GHz, an additional attenuation is necessary as oxygen absorption limits the transmission range. Both the cases result in small cell as compared to microwave bands such as 2.4 or 5 GHz, requiring numerous BSs to be deployed to cover a broad service area.

2.3 A Single fiber with Multiple Services

One of the greatest motivations to RoF is that is its transparency to protocol and radio interface format which includes modulation, RF, bit rate etc. Therefore, a single fibre can support multiple services simultaneously. Larger transmissions distances between the Centralized Station and Base Station are possible. The system has an immense potential to support high capacity and wireless access networks which are cost effective. The centralized network architecture in RoF technology allows capacity allocation and dynamic radio resource configuration. Furthermore, centralized upgrading is also possible.

2.4 Low Attenuation

Another motivation for RoF was that the attenuation is low, lowest attenuation is 0.2dB/km at 1.55 μm band. Due to this low attenuation much greater distances are achievable without the use of repeaters. The attenuation is not dependent on the modulation frequency. [3]

3 Some eminent benefits

1) The large RF propagation loss at the bands of BS can reduce the cell size. [4]

2) The spectrum utilization efficiency can be improved by increasing the frequency reuse factor which can be achieved in this technology. [4]

3) Simpler, smaller size & low-cost base stations.

4) Because of the smaller cells, higher bandwidth is allocated to end-users.

5) Could be accommodated with passive optical network (PON) Infrastructures.

6) Can use multiple techniques including wavelength division multiplexing (WDM) technique for improving the network throughput.

4 METHODS

Three methods are discussed below through which this technology can be implemented.

4.1 SCM (Subcarrier Multiplexing)

Optical subcarrier multiplexing is a system in which more than one signals are being multiplexed in the domain of radio frequency and then being transmitted using a single wavelength. Its advantage is that devices with microwave are more mature as compared to optical devices. Selection of frequency in a microwave filter and stability are much better in a microwave oscillator as compared to optical. Coherent detection becomes easier in the radio frequency domain because of RF oscillators with low phase noise as compared to in optical domain and modulation formats that are advanced are applicable simply. A common application of this scheme is analog cable television in fiber optic systems. [5]

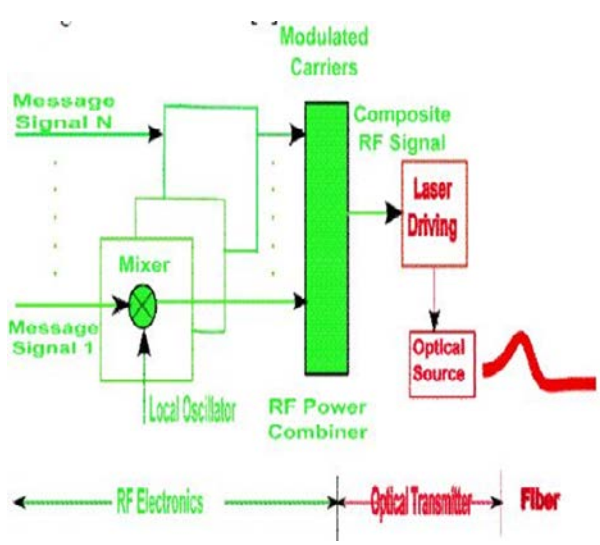

Fig1

4.2 WDM (Wavelength Division Multiplexing)

It is passive device that combines signals of light with different wavelengths coming from multiple fibres to one fibre. This requires DWDM i.e. dense wavelength division multiplexers. Analog (optical) techniques of multiplexing are being used by these devices for increasing the capacity of carrying of networks of fibre above levels, which are achieved using TDM (time division multiplexing). RoF signals distribution illustrated in figure using WDM is becoming importance nowadays. Efficient utilization of the bandwidth of fibre network is being enabled. Such systems are able to achieve capacities of 1 Tb/s for a single fibre. Single channel has bit rates raised to 10 Gb/s and 40 Gb/s channel rates of systems are available at commercial level. Spacing of channel can be reduced to 50 GHz or even to 25 GHz that makes possible the usage of channels, hundred in number. But, if the 50 GHz rather than 100 GHz is the reduction in spacing of channel will make upgrading of the systems that are operating at 40 Gb/s much harder because of the effects that are non-linear in nature. [5]

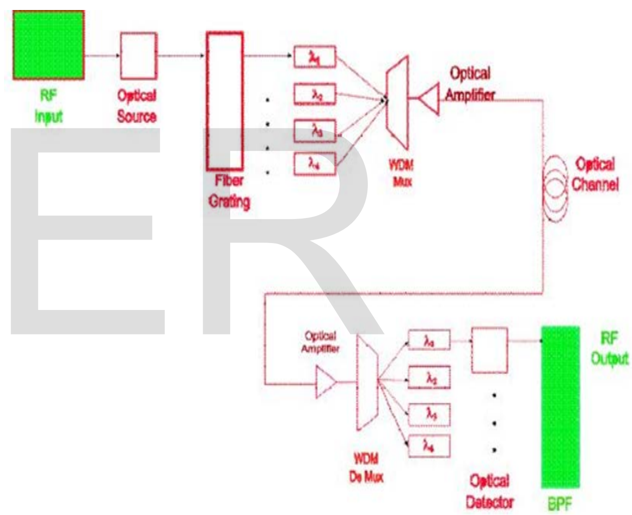

Fig2

4.3 Optical Frequency Multiplexing

This RoF technique is cost-effective and flexible which enables multiple functions needed for supporting systems for accessing wireless. RoF distribution antenna systems based on OFM are being merged smoothly with broadband accessing networks that are similar to WDM-PON that allows a convergence of optical fibre's high capacity and flexible access in wireless. Antenna systems for RoF distribution in which there is generation of radio signals at a remote central station (CS) and then transparent distribution to numerous antenna stations (AS) by making use of optical fiber. The key objective of RoF systems is overcoming the capacity bottleneck in access of wireless networks, reduced cost of infrastructure and allowing a flexible merging with conventional optical accessing networks at the similar time. For designing infrastructure-using RoF based access, which is reliable, Radio over fibre techniques should have capability of generating microwave sig-

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nals and allow a reliable transmission using the optical link. This technique of RoF is able to satisfy these two essential needs by generation of the microwave signals by usage of a single laser source and low frequency as well. As compared to other RoF techniques, the principle is a method tolerant in dispersion that generates microwave frequencies optically and delivers wireless signals to a distant antenna stations as well. [5]

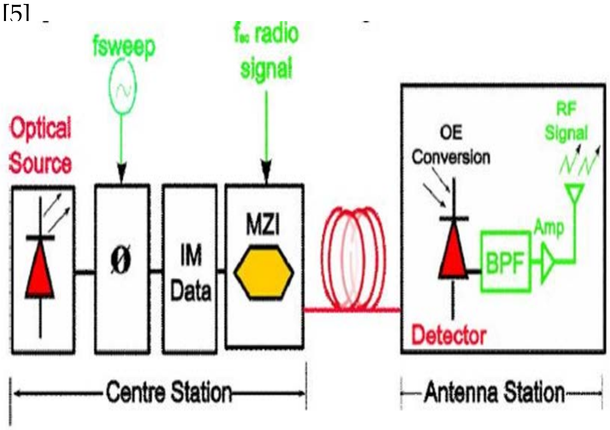

Fig3

5 APPLICATIONS

Radio over fibre is a vast technology and its applications can be found in a numbers of areas. [6]

5.1 4th generation

1) Fourth Generation would arrange least bit rate for broadband amenities i.e., 20 Mbps for indoor solicitations. Radio over fiber is used in indoor communication.

2) 2Mega b/s for outdoor solicitation even with high Fundamental mobility.ROF is used also in outdoor communication.

3) Two systems that are much interesting in mobile communication field are 4G and (Intelligent Transport System)

4) Concept in 4th Generation cellular structure is cell optimization. In its structure, the key technology in path automobile communication structure is Radio over Fiber, in which several base stations are prepared along the trunk path in order to connect with automobiles.

5) The foremost source of noise and distortion in Radio over Fiber is laser basis.

6) By analyzing the appropriate laser basis which has right stability between charge and performance, the indoor Radio over Fiber technology basically can be applied

5.2 Wireless Access

1) In initial ROF structures, Radio over fiber technology is mainly used to transport the microwave signal and to achieve mobility.

2) Radio over fibre technology is also used for the wireless access which mainly involves the radio wave communications.

3)Modified MV signals had to stand available at the input of Radio over Fiber system, which then conveyed them over a distance to the RS in the form of optical Radio over Fiber networks.

5.3 General Applications

1) Another application of Radio over Fiber is that it delivers wireless exposure in the area where the wireless signals cannot approach, these areas also known as "red zones". For example, the areas under huge assemblies, behind erections or the forests.

2) The highest data rates are available in band frequency. Communication quality of band is greatly reliant on climate. According to the climate conditions the parameters are selected. In these severe adverse climates, Radio over Fiber broadcast structures are selected because it consumes less cost and have good quality

6 QUALITY PARAMETERS

6.1 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 spectrally less efficient. Though noise robustness of BPSK is a little 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 [5].

6.2 Scattering

One of the major impairments is stimulated Brillouin scattering. SBS limits the amount of optic power that can be inserted into the fibre without affecting the quality of the signal. In RoF, if we choose a segmented single mode fibre, then the transmission can be strongly suppressed. 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. [5]

6.3 Carrier to Noise Ratio

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.[5]

6.4 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.[5]

7 CHALLENGES

Some challenges have to be addressed while increasing the RoF penetration in the network.

7.1 Protocol

One single protocol is being used for aggregate and for transferring different services' digital data in current addressing system. However, is different when using RoF, several protocols that are parallel are being used and the services transportation is done on their native protocols transparently. [5]

7.2 Architecture's Cost

Optical infrastructure mutualisation between the different network kinds having different evolutions arise RoF in access networks. There is a need of developing a scenario over current Access Networks architectures for using RoF. Cost savings demonstration is the challenge that should be comprehended today for usage of RoF for the deployment of Wireless access and Mobile with present optical infrastructures. [5]

7.3 Standardization

There is lack of standardization in RoF. For millimetre-wave and photonic converter to microwave, which are used in communication systems of RoF, the standard specifying measurement methods are being established and maintained by very initial work. Currently, the architectures and techniques being used in RoF are very diverse and identification of some sufficient solutions are must needed. [5]

8 CONCLUSION

In this paper we introduced the basic concept of Radio over Fiber Technology. The motivation and major benefits of this technology were illustrated briefly. The main modulation schemes were discussed along with their quality parameters.
We conclude that RoF is a flexible and costeffective technique that enables multiple functionalities required for the support of wireless access systems. Surely there are many challenges that are being faced by the RoF technology but it vividly has a wide scope and in the future.

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REFERENCES

1. http://onlinelibrary.wiley.com/doi/10.1002/9780470744857.ch7/summary;jsessionid=DAD8DA65A80518650EBB77F1F6221C53.f02t03
2. http://discovery.ucl.ac.uk/1299501/
3. http://cms.comsoc.org/SiteGen/Uploads/Public/Docs_Globecom_2009/XavierROFT16.pdf
4. https://www.tkn.tu-berlin.de/fileadmin/fg112/TKN-dissertations/kim_hongbong.pdf
5. www.ijettcs.org/Volume1Issue2/IJETTCS-2012-08-25-130.pdf
6. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4603945