A New Topology for Telecom and Broad Band Services in Spars, Remote and Hilly Areas

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Abstract:-Technological development and mass scale deployment of mobile telephony in the last 15-20 yrs has made telecom services an essential commodity for the modern age society. Affordable and wide spread availability of telecom services is giving impetus to digitalization of all the contents and leading to convergence of telecom, media and broadcasting. This phenomenon is further accelerating the demand for higher bandwidth, while at the same time there is a limitation in the availability of additional spectrum and is posing problems due to increased power consumption by telecom systems, ill effects of excessive electromagnetic radiations and scarcity of backbone for carrying telecom traffic. To overcome the above problems there is a need for defining new topologies for telecom and broadband deployment befitting the terrain and population density, particularly in the thinly populated, remote and hilly areas where making available regular power supply for operating telecom infrastructure round the clock and installing backbone infrastructure in the conventional way is impractical and not cost effective.

A study is attempted to define a new telecom network deployment topology that would reduce the power and backbone backup required by almost 50 times while at the same time, increase and make available broadband connectivity on demand and also reduce the ill effect of electromagnetic radiations in a phenomenal manner. The authors have attempted to vary the capacity and coverage, of telecom services provided, based on the requirement, and have also phenomenally increased the coverage provided by the mother BTS by increasing its height by almost 10 times by placing it in a tethered balloon. While this would provide uniform umbrella coverage with low traffic capacity over a large area i.e., upto 5000 Sq Kms, enhanced capacity would be provided in pockets under this umbrella in populated residential area (villages) and office complexes by installing very low power BTSs which are equivalent system capable of being operated using alternate sources of energy like wind, solar etc and also cause negligible electromagnetic radiation pollution. The umbrella coverage provided by the mother BTS will communicate with these low power BTSs and will also provide backhaul connectivity.

Key-words:-BTS, Flexible Tower, Communication, CDMA

1. Introduction

Mobile phones with all its modern day applications and features has brought in a communication revolution worldwide. Initially communication services were used mainly for the purpose of administration and for military applications. On realizing the fact that telecommunication and broadband services can become basic drivers for economic growth, job creation, poverty elimination and most importantly to create a knowledge based society, world over, different governments introduced telecom reforms and started involving the private sector for providing telecom connectivity and services. Last 15 years has seen an unprecedented phenomenon in the history of civilization where more than half the population globally is connected to a network by which they can talk to each other, exchange views, go for social networking etc. This has changed the entire landscape of the way we work, do business and communicate with each other.

The impact of this communication revolution has been manifold and more effective in a developing and highly populated nation like India. Unfortunately the maximum chunk of mobile connections are concentrated in the urban areas. The small percentage of connections available is rural areas are limited to those villages along railway lines and highways where service providers had erected towers and BTSs. Service providers shy away from setting up these infrastructure and facilities in remote villages due to the administrative difficulties, economical viability and maintenance problems involved. Due to these constraints, in India, two different social groups have been created, the baseline being a digital divide, one group with telecommunication facilities and the other without. The conventional telecom towers and BTSs which have a height of 40-60 m cover an area of 120-150 Sq Kms. If the sparsely populated and far flung rural India, actually being 70 % of population is to be provided the same quality of telecom facilities available to the urban population, a large number of towers and BTSs with their backhaul fiber/microwave links need to be set up. As the grid electricity supply in most of India is not reliable, these facilities depend on diesel generator for power supply. India has 3,75,000 towers and each tower is supported with a 15-25 KW DG Set [1]. It was estimated that about 2 billion Lts of diesel is burnt annually to operate the existing towers in India and would increase to anything between 14-16 billion Lts a year if the towers and BTSs are proportionately increased to provide facilities to all areas covering remote rural India. This would increase the running costs exorbitantly and to add to the insult there will be significant increase in the carbon footprint in the atmosphere due to excessive burning of diesel. The other important hazard of this massive increase in BTSs will be the excessive electromagnetic radiation with all its well known health hazards [2,3].

Keeping these above issues in mind, it was conceived that instead of increasing the number of towers and BTSs, we could increase the height of position of the BTS to a level that is feasible, thereby increasing the geographical area covered by a single BTS. This would result in being able to provide effective and efficient telecommunication facilities in and between villages at low costs and at the same time not increase the ecological hazards of increased carbon footprint and radiation hazards. With the aim of achieving these goals a study was conducted in association with TIFR at Hyderabad, in which the height of BTS was raised to about 500 m with the help of a tethered balloon. The details and results of which are explained in details in this paper.

2. The Approach

The authors, after studying the present network deployment approach have come out with a new innovative concept of dividing the capacity and coverage variance in the two different parts of this study.

A super umbrella coverage was considered by deploying a flexible floating tower at a height of approx. 500 to 700 m. Such a system can provide low capacity umbrella coverage in a area of 5000-7000 Sq. Km. A preliminary study on these lines was done and results were presented at the COSPAR[4]. In each inhabited area (Village/office Complexes located in remote area) small pole mounted BTSs with maximum radiated power of 2-10 watts. may be installed to provide mobile/ fixed line high capacity connectivity. These low power small BTSs can be operated using alternate source of energy like solar, wind etc. and thus totally eliminate the need of unreliable grid supply. The floating platform will provide back haul connectivity to these pole mounted BTSs, for connectivity to the main telecom network elements like BSC and MSC.

This approach will eliminate the need of high cost of the power supply in the remote area, need of digging long trenches for providing costly fiber/ microwave connectivity for backhaul and will relieve the society of high intensity excessive electromagnetic radiation. This system will reduce the power consumption and the backhaul requirement to the tune of 50-70 times thus making phenomenal saving in OPEX and CAPEX. Further the system with proper modification will become excess technology agonistic. Using such a system, telecommunication, broadband and broadcasting services can be provided in a highly effective manner in rural and remote areas impractically in no time.

The small 2 watt to 10 watt solar energy operated, pole mounted BTSs have emerged as a new technological breakthrough. This solves the second part of the puzzle. Since the floating flexible tower still requires a lot of R & D activities for making it a commercially viable system, the present low energy excess system uses microwave for back hauling.

3. The flexible floating tower approach

A standard BTS with proper antenna system was lifted to a height of about 500 meters using a gas filled balloon and gondola. In order to prove the concept of floating flexible tower a 350 Cubic meter spherical tethered balloon and a motorized winch (Fig. 1) was fabricated at National Ballooning Center of TATA Institute of Fundamental Research at Hyderabad. The selected tethered was capable of handling a weight of approx. 1.8 tones. A payload containing modified CDMA BTS system, antenna system and other sub assemblies was lifted with the floating tethered balloon as shown in Fig. 2 and 3. The provision for requisite power supply for operation of BTS and fiber backhaul connectivity to the floating platform was made available from the ground. A microwave link was established from the site to the BSC and MSC of live CDMA telecom system as shown in Fig. 4. The field measurement of the signal strength and call setup and tear off was done using live test tools and densely populated CDMA handsets in the areas of coverage [5,6].

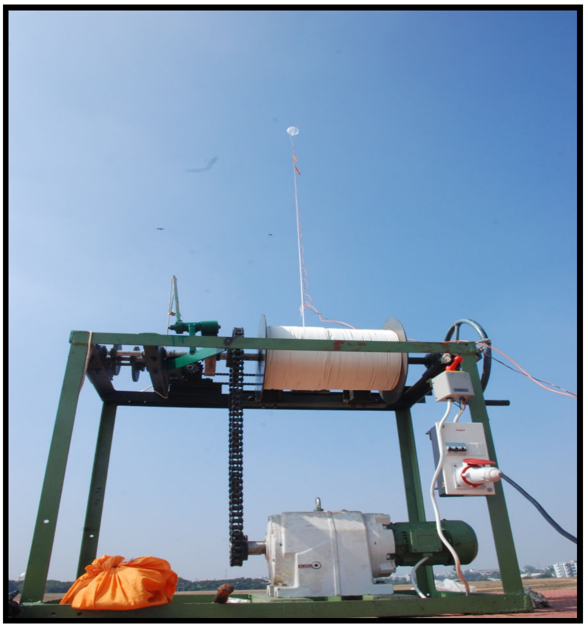

Fig. 1 Hoisting winch

Fig. 2 Inflated balloon

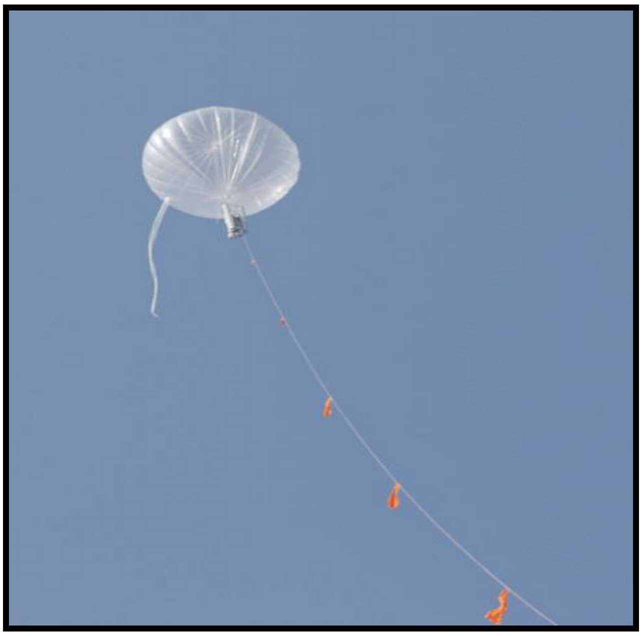

Fig. 3 Inflated balloon

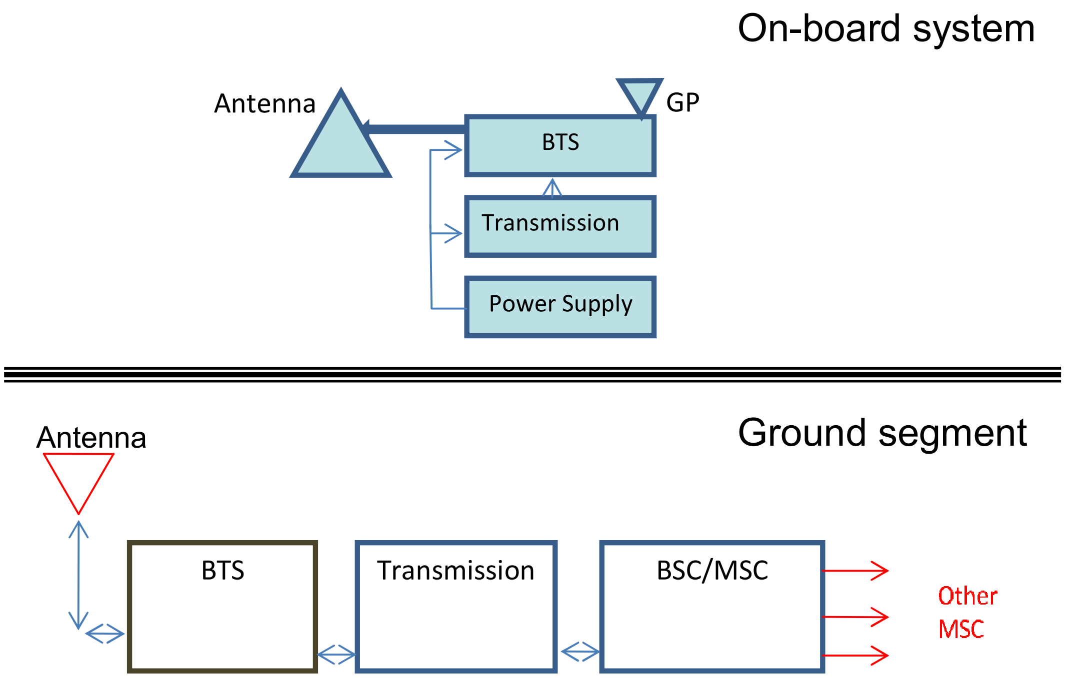

Fig. 4 Experimental scheme

BSC: base switching center

MSC: master switching center

3.1 Payload Details

3.1.1 Power Supply

A constant uninterrupted power supply was required for the continuous operation of BTS and other payload systems. The power was routed along with the tethered from the ground after making the proper modifications in the payload.

3.1.2 BTS

A properly modified light weight CDMA BTS was made for operation in 800 MHz band. The requisite spectrum allocation for the field trail was obtained from wireless planning and coordination division of department of Telecommunication, Govt. of India. A GPS and proper telemetry system for accurately measuring the height of the system and to know the health of the floating platform during the flight was installed in the payload.

A properly modified antenna system capable of working in 800 MHz CDMA band was attached to the BTS. The fiber from the ground was properly terminated at the BTS for connecting to main telecom network using a microwave link from site of trails to the location of BSC and MSC.

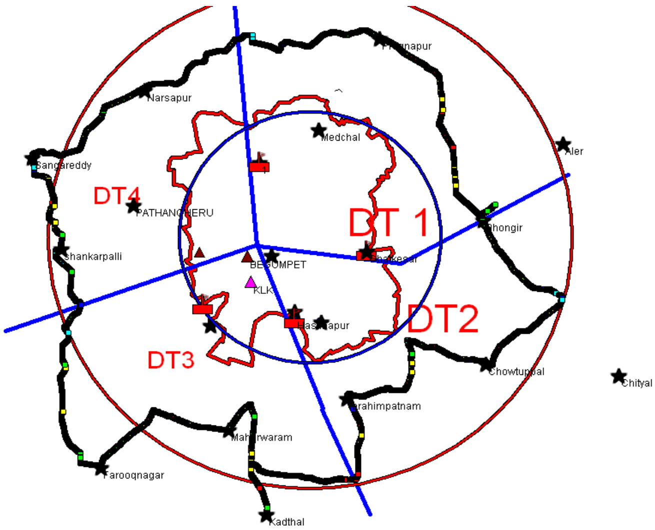

Fig. 5 Field Requirements

3.1.3 Balloon

The balloon was filled with the lighter than air gas for lifting the entire system to a height of approx. 500 m. Proper telemetry system was deployed for regularly monitoring the health of the system during the operation. The system was made live after reaching the requisite height of 500 m. Four drive test system teams were deployed for taking the measurements during the flight at different heights of the flexible platform. A good number of handsets were deployed in the entire converge area for receiving and transmitting voice and data calls.

3.2 Field Operations

Drive tests were conducted in a radius of about 60 Km at different heights during the ascent of the floating flexible tower. The parameters of communication links were measured at the drive test unit and the MSC. The results of the drive test were compared with predicted values obtained using standard drive test tools.

3.3 Test results

The test was carried out at 300 and 500 meters height. This was done at 20% and 30% of pilot power. The tests were carried out at locations as shown in Fig. 5.

3.3.1 Predicted Vs Drive test Plots

The Predicted Vs Drive test plots were taken for three cases.

Case 1: 500 m Height 3 degree tilt of antenna, 30% pilot power as shown in Fig. 6

Case 2: 500 m Height 3 degree tilt of antenna, 20% pilot power as shown in Fig. 7

Case 3: 300 m Height 3 degree tilt of antenna, 30% pilot power as shown in Fig. 8

Legend
Mobile TX Prediction

	--->	-7 dBm
	--->	8 dBm
	--->	15 dBm
	--->	23 dBm

Legend
Mobile TX _Drive Test

	---->	Below -10 dBm
	---->	-10 to 0 dBm
	---->	0 to 10 dBm
	---->	10 to 20 dBm
	---->	Above 20 dBm

Case-1: 500m height of Flexible Tower, 3 deg tilt of Antenna & 30 % Pilot power

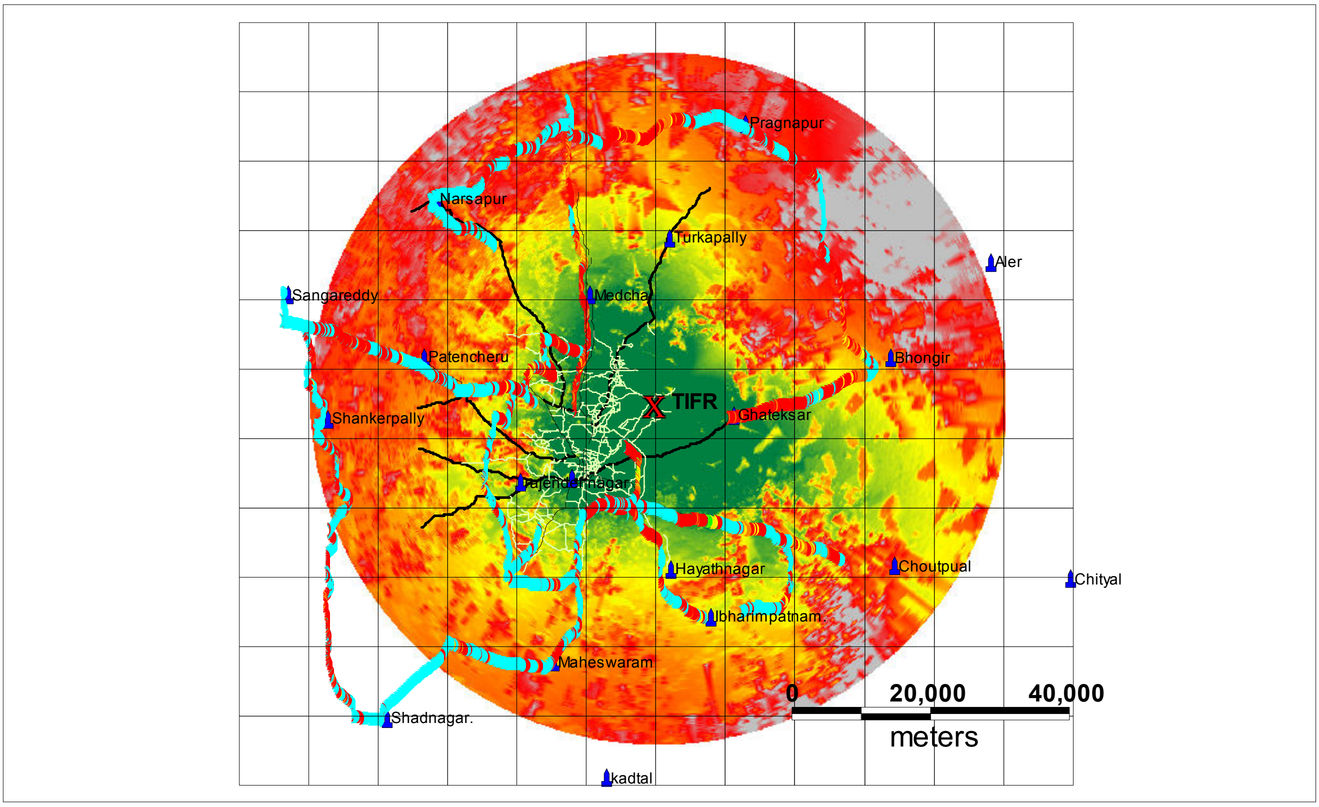

Fig.6 Predicted v/s Drive Test Plots

Legend
Mobile TX Prediction

	--->	-7 dBm
	--->	8 dBm
	--->	15 dBm
	--->	23 dBm

Legend
Mobile TX Drive Test

	---->	Below -10 dBm
	---->	-10 to 0 dBm
	---->	0 to 10 dBm
	---->	10 to 20 dBm
	---->	Above 20 dBm

Case2: 500m height of Flexible Tower, 3 deg tilt of antenna, 20% Pilot power

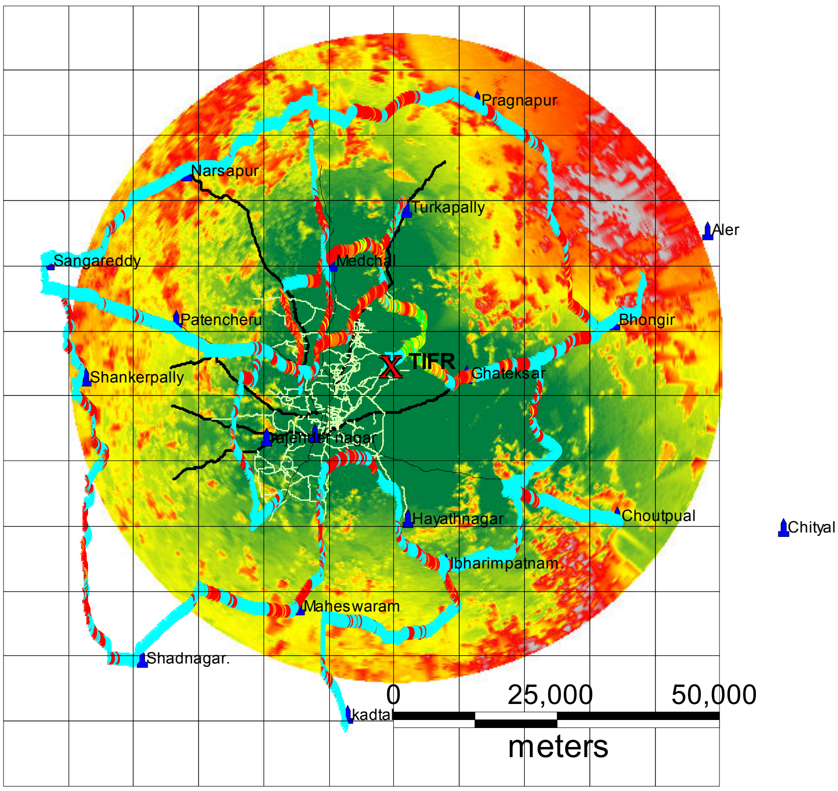

Fig. 7 Predicted v/s Drive Test Plots

Legend **Mobile TX Prediction**		
	--->	-7 dBm
	--->	8 dBm
	--->	15 dBm
	--->	23 dBm

Legend **Mobile TX Drive Test**		
	---->	Below -10 dBm
	---->	-10 to 0 dBm
	---->	0 to 10 dBm
	---->	10 to 20 dBm
	---->	Above 20 dBm

Case3: 300m height of Flexible Tower, 3 deg tilt of antenna, 30% Pilot Power

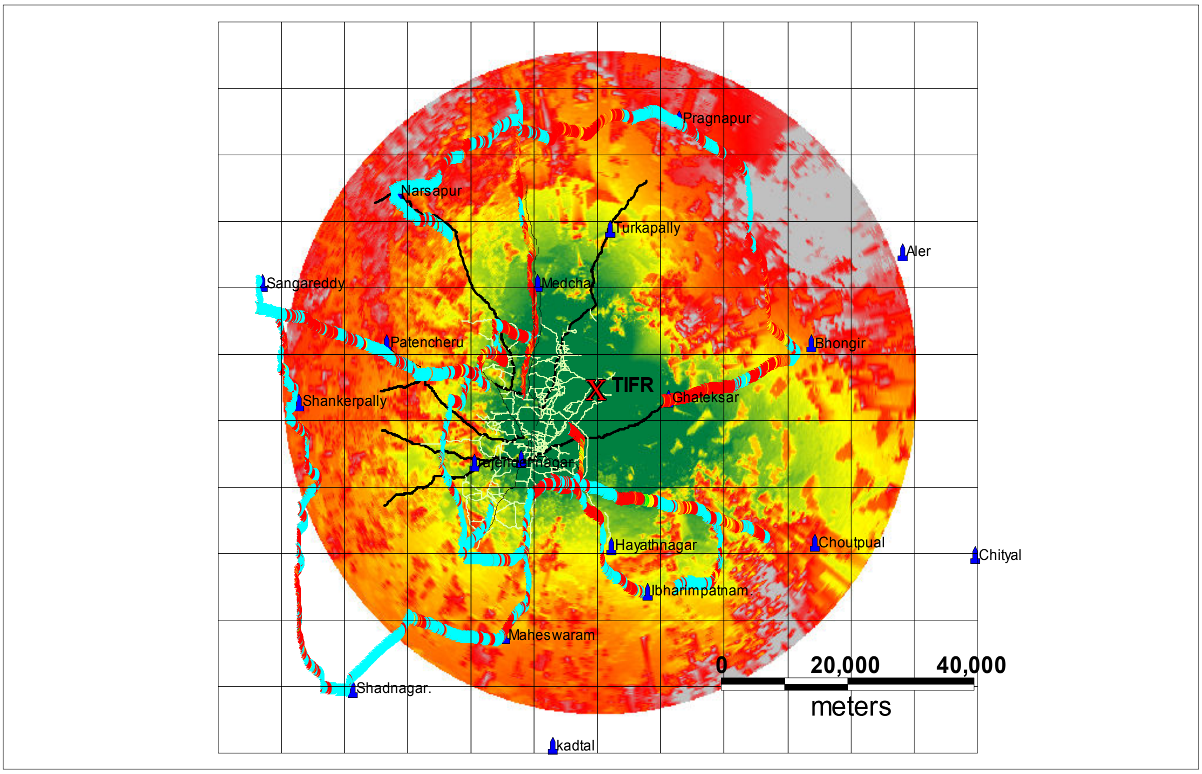

Fig. 8 Predicted v/s Drive Test Plots

3.3.2 Prediction Vs poling values

The details of test results at 300 and 500 m height at different pilot power are given in details in Table1.

Table 1 Predicted Vs Polling Values

		500m Height of Flexible Tower, 30% Pilot power		500m Height of Flexible Tower, 20% Pilot power		300m Height of Flexible Tower, 30% Pilot power	
Fixed Location Name	**Distance from Site of Flexible Tower (in Kms)**	**Predicted Value**	**Measured Value (Field drive test)**	**Predicted Value**	**Measured Value (Field drive test)**	**Predicted Value**	**Measured Value (Field drive test)**
Medchal	21.20	-7 dBm	25.7 dBm	-7 dBm	-33.7 dBm	-7 dBm	27.5 dBm
Narsapur	41.30	21 dBm	-38.2 dBm	21 dBm	-35.8 dBm	23 dBm	-34.9 dBm
rajender nagar	27.20	-5 dBm	-24.3 dBm	-2 dBm	-38.5 dBm	1 dBm	-41.8 dBm
Ibharimpatnam.	34.10	3 dBm	-40.4 dBm	2 dBm	-39.5 dBm	14 dBm	-40.7 dBm
Ghateksar	11.18	-7 dBm	-46.4 dBm	-7 dBm	6.4 dBm	-12 dBm	-46.7 dBm
Bhongir	34.10	5 dBm	-49.6 dBm	8 dBm	-41 dBm	15 dBm	-45.9 dBm
Patencheru	34.10	8 dBm	-42.8 dBm	9 dBm	-40.6 dBm	23 dBm	-41.1 dBm
Pragnapur	41.88	15 dBm	-38 dBm	17 dBm	-34 dBm	23 dBm	-27 dBm
Shankerpally	47.43	10 dBm	-52.5 dBm	8 dBm	-42.1 dBm	23 dBm	-54.5 dBm
Sangareddy	55.20	Out of prediction boundary	-58.9 dBm	Out of prediction boundary	-44 dBm	Out of prediction boundary	-38.6 dBm
Shadnagar	60.41	Out of prediction boundary	-44 dBm	Out of prediction boundary	-41 dBm	Out of prediction boundary	-56.8 dBm
west maredpally	16.76	-7 dBm	-24 dBm	-10 dBm	Not done the drive	-5 dBm	Not done the drive
Maheswaram	40.94	8 dBm	-38.7 dBm	10 dBm	-46.7 dBm	15 dBm	-38.5 dBm
kadtal	55.34	N/A	N/A	Out of prediction boundary	-40.8 dBm	N/A	N/A
Hayathnagar	18.05	-4 dBm	17.6 dBm	-6 dBm	-39.2 dBm	5 dBm	-41.2 dBm
Choutpual	43.80	7 dBm	N/A	6 dBm	-51.6 dBm	23 dBm	Not done the drive
Turkapally	23.40	8 dBm	Not done the drive	2 dBm	-6.6 dBm	6 dBm	N/A

3.3.3 Analysis of actual field measurements V/S Predicted result

The test results were compared with the predicted values using the standard predication model used in drive test units for different power level at different height (500, 300 m) of the floating flexible tower. The drive test and the observations at the fixed location shows that the receive power level varied at different location depending upon the clutter, terrain and other physical parameters. In some of the places a signal could not be predicted due to sway of the floating platform due to high winds and other related factors. It was observed that the actual measured values are far better than the theoretically predicted values. This is due to the fact that in sparsely populated remote areas the clutter and terrain are entirely different from the urban areas and the transmission and reception of signal was coming without much of the multiple reflection and obstruction due to the height of the flexible tower. The trial proved very clearly that with proper modification in the payload and the relevant system the concept can provide umbrella coverage to an area of 5000-7000 Sq. Km. easily and effectively shown in fig. 9 [7].

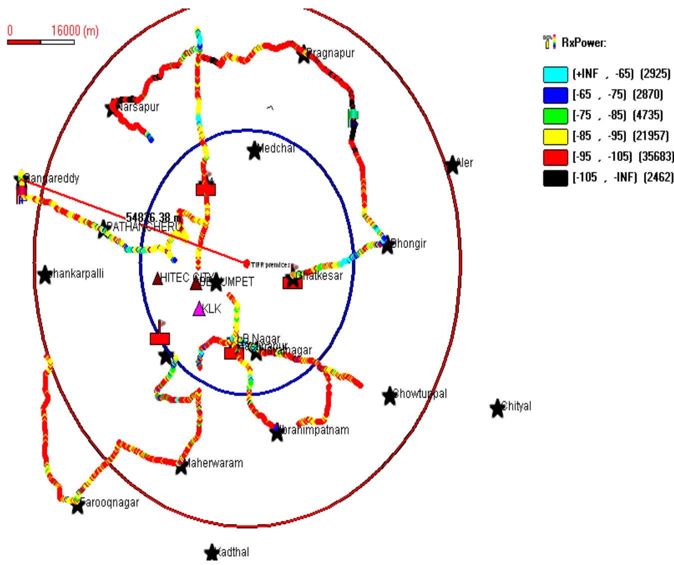

Fig. 9: Field measurements

4. Approach to provide high capacity in area of inhabitation (Villages/office Complexes)

The second part of approach is to provide high capacity in the areas where it is needed. The conventional urban architecture with 40-60 m high tower, radiating all across does not serve the real purpose as the communication facilities are required to be provided in a thinly populated localized pockets of inhabitation. The conventional architecture provides equal capacity and coverage at very high cost even in the agricultural field, lakes, river etc. which is a total wasteful expense of costly resources. Added with very low ARPU, the operators do not find such networks very attractive due to economically unviable business proposition. This is resulting in a big digital divide between urban and rural population. Since 70% of Indian population lives in villages it is imperative to find out innovative solutions to provide voice and data in the rural area at affordable cost. Further 65% -70% rural population is not well literate and hence it is necessary to provide local assistance services in their own environment dealing with their own activities and with their problems.

In recent past, some of the innovative organizations like VNL, MIDAS, POWERWAVE etc. have tried to redefine the standard GSM architecture for use in such thinly populated remote areas.VNL has pioneered this concept and has developed highly innovative technology by redefining the standard GSM system with voice and data capability. Fig. 10, depicts the network architecture of such rural GSM telecom networks developed by VNL.

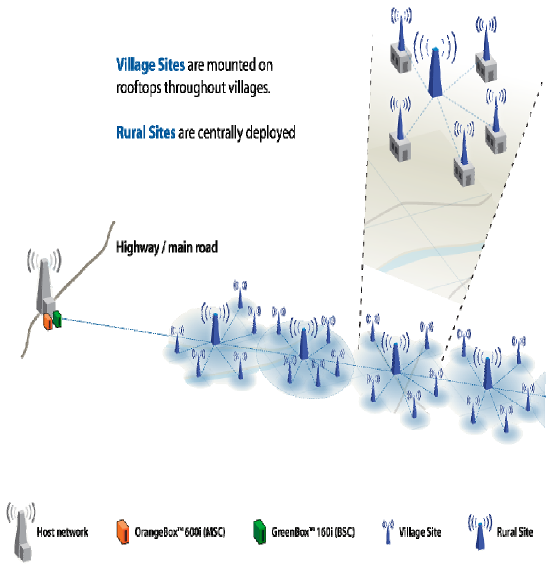

Fig. 10 network architecture

The system uses pole mounted very low power village BTSs capable of working with solar energy. The system contains a pole mounted BTS, antenna system, battery bank, solar panels, other related subsystems and a microwave radio for back haul connectivity to a central tower. The entire village BTS can be installed and made operational by two semi skilled persons in 6 hours time. These BTSs are capable of providing data connectivity by making a Wi-Fi hotspot in the Village. The rural and village BTS are shown in Fig. 11 and 12 [8].

Fig. 11: Rural Village BTS

Fig. 12: Village/Central BTS

A 40 m high central tower connects the rural BTSs around it using microwaves links, thus forming a cluster. A BTS at the central tower provides low capacity Umbrella coverage in the entire footprint of the cluster. The equipment at the central tower consumes power to the tune of 150 Watts and operates on solar energy. A good number of such clusters form a dizzy chain and connect to a BSC and a good number of BSCs are connected to a MSC forming a complete network. The system gets integrated with other GSM networks using standard interface and protocols as shown in Fig. 10.

Since the rural population is not well literate they require assisted services to use the information in digital domain. Such systems are being extensively deployed in different parts of the world using local entrepreneurs. This enables the creation of a local communication center in a village to provide communication facilities. This local communication center also facilitates in charging of handsets, repairing, after sale services, providing lots of value added services like e- ticketing, birth certificate, driving license, land records, video conferencing, health services, education services, mandi rates and agriculture related informations etc. Since the rural population is not computer savvy this center will also impart computer and internet education [9].

5. The proposed network topology

In the coming years, with the increasing and extensive use of internet, broadband and telecom services for improving the quality of life of a common man living in a remote area, the requirement of back haul will increase manifold. At the same time the supply of grid electricity is not expected to keep pace with telecom and broadband uses, hence there will be a big gap between demand and supply of electricity and back haul for telecom applications.

In order to take care of the requirement of power supply and the back haul, it is proposed that the floating flexible tower and the village BTS concept may be tied together in a meaningful manner. By doing so the floating flexible tower will provide low capacity super umbrella excess network coverage in an area of 5000-7000 Sq Km. This floating flexible tower will provide very high capacity back haul connectivity to the rural BTSs for providing broadband connectivity. This would eliminate the need of digging and maintaining the trenches upto the villages for providing fiber connectivity to a great extent. At the same time since one super umbrella will replace so many big towers the power, operation and maintenance requirement will reduce CAPEX and OPEX in installation and maintenance of conventional towers in a phenomenal manners shown in Fig. 13 [10].

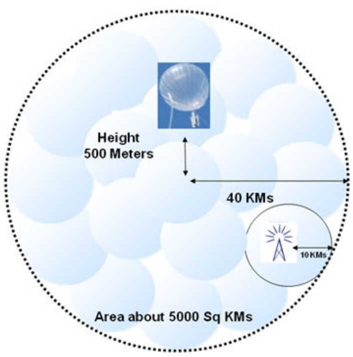

Fig. 13: One extended tower can cater to an area covered by 35-40 convectional towers

It is expected that the ill effects of sustained exposure to the electromagnetic radiation of the conventional telecom (topology) towers are going to create a lot of health and ecology related issue in years to come. The flexible tower due to its height of 500-600 m and due to the fact that it would replace a large number of conventional BTSs will reduce the ill effects of electromagnetic radiation to great extent. In order to reduce the cost of backhaul, CAPEX and OPEX involved in installation and operation of big telecom towers in remote areas, further research work and engineering developments are required that will enable the local BTSs to remain in continues contact with the flexible tower for back haul connectivity[11].

The flexible tower is excess technology agnostic. The different types of excess technology like GSM, CDMA, WIMAX, LTE etc can be deployed depending upon the need of the rural population to provide high band connectivity in the rural and remote areas, as the flexible tower carries fiber for back haul connectivity. A lot of development work is required to make the floating platform stable for providing sustained connectivity. Depending on the terrain and the requirement the height of the floating flexible tower can be adjusted to cover a given geographical area. A standby flexible tower need to be considered when the main one is brought under maintenance for uninterrupted communication. While a conventional BTS covers an area with a radius of 6-7 Km, the area covered would increase to a radius of 50-60 Kms by increasing the height of the flexible tower to 500 m. Thus it would replace about 30-35 conventional tower for covering the same area.

6. Conclusion

The research work reported and the proposed architecture will create a different network topology which will be the answer to the digital divide created between urban and rural India. It will help to bring in the 70 % of Indian population living in villages into the mainstream of economic growth in India, encouraging them to become active participants in the growth. This system is also highly cost effective and eco friendly. On a later date after making the requisite modifications this system can also be adopted in urban areas as it is definitely a better system with its much better cost effectiveness and the great benefit of phenomenal reduction in atmospheric carbon footprint and electromagnetic radiation.

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BRIEF BIO – DATA

Prof. P. K. Chopra

Prof. Pradeep Kumar Chopra entered the field of education in the year 2004 after 24 years of exemplary service in the technical branch of the Indian Air Force, He earned his Bachelor's degree in Engineering (Electronics) from Delhi college of Engineering in the year 1979 and Masters in Technology from IIT Delhi in the year 1985. He also has a Masters degree in Defense Studies from Madras University. While he was in the Indian Air Force he was part of and headed a number of important technical projects. For his exemplary services he was awarded "Vishist Seva Medal" by the President of India in the year 1993.He took early retirement from the IAF in the year 2004 and entered the field of education. He is the Head of Dept. (Electronics and Communication) in Ajay Kumar Garg Engineering College in Ghaziabad.

Prof. R. K. Manchanda

Prof. R. K. Manchanda started his research career at TIFR in 1966 at the age of 19 years. He pioneered X-ray astronomy and has built many new and innovative detectors and payloads for Spectral and Temporal studies in X-rays. During his long career of 45 years, he has conducted large number of balloons and Rocket experiments and also launched the X-ray Sky Monitor experiment, on board Second Indian Satellite `BHASKARA' in 1979. In addition, to his ongoing balloon borne research program in X-ray astronomy, he is the program manager for the LAXPC payload on board Indian astronomy satellite, ASTROSAT to be launched in 2011. Prof. Manchanda has launched almost 50 scientific balloon flights from various parts of the World. Presently he is working as Senior Professor, in Tata Institute of Fundamental Research, Mumbai.

Dr. R.K. Mehrotra

Dr. Rakesh Mehrotra is a telecom professional with more than 35 years of working experience in the field of telecommunication and broadcasting and satellite systems. He worked as President Tata Teleservices and was instrumental in establishing Tata Telecom Centre of Excellence and worked as co-coordinator in the initial stages. He was instrumental in establishing India's first DTH platform and was deeply involved in development of Agrani Satellite System for GMPCS and broadcasting applications. His current areas of interest are telecom sector reforms, development and deployment of low intensity electromagnetic radiation, low power, low carbon telecom systems, and new telecom deployment topologies for efficient use of spectrum, backhaul and energy resources particularly in rural and remote and sparsely populated areas to start with.

Prof. (Dr.) Shail Bala Jain

Prof. Shail Bala Jain is having nearly 32 years of experience in the field of education. She earned her Bachelor's degree in Engineering (Electrical) from Delhi college of Engineering and Masters in Technology from IIT Delhi. She completed her doctorate from Delhi University. Her area of interests is Analog Electronics, Linear integrated circuits and digital signal processing. Currently she is the Head of Dept. (Electronics and Communication) in Indira Gandhi institute of Technology, New Delhi.