Cost Effective, Solar Powered, Low Bandwidth (11 Mbps 802.11b) WiFi Access Point Network for Voice (VoIP) and Data Traffic from Villages

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Abstract:
This paper targets the telecom industry. It aims to establish a mechanism to route voice traffic at specific areas with the condition that the traffic originating within the specified area does not cross the boundary at any point and has to end within the specified area(village), where the calls are not routed to PSTN that is they need not go to the Telecom operator. This works in dual mode that is if the traffic is outside the boundary then it is routed to PSTN / GSM etc Network, otherwise internally routed. Cell phone network (GSM / CDMA) providers do not cater for villages, because of high cost of BTS, BSC and MSC and non availability of power in KW range for the nodes. To address this, the solution proposed is: Using internet technology with solar power is possible for the infrastructure( roughly one tenth or lesser cost).Cost reduction of infrastructure is due to use of low cost outdoor WiFi nodes, and use of high gain omni antenna. Because of the large mobile internet user requirements, the cost of wireless LAN radio terminals (WIFI access nodes /hotspots) has come down drastically. These nodes cater for voice traffic (voice over IP – VoIP) also and hence the telecom network for villages can easily be set up, based on VoIP internet voice technology. Reserving some bandwidth for data, enables for wide variety of applications like telemedicine, distance education etc.

Keywords: GSM, CDMA, PSTN, VoIP.

I. INTRODUCTION

Voice over Internet Protocol (VoIP) [1] is a type of transmission that permits any individual to make telephone calls over a broadband internet connection. VoIP access generally permits the client to call other people who are likewise accepting calls (over IP based infrastructure like W-LAN(WiFi Access Point / Hotspot), Router, IP switches ). Interconnected VoIP associations additionally permit users to make and get calls to and from regular landline numbers, (using gateway routers), as a rule for an administration charge. It is well known that decades old GSM technology implementation with many analog components and sub systems, is highly expensive to service thin, essentially voice, traffic areas in villages. Not so rich, villager cannot afford high bandwidth data download or watching real time movies. Moreover, even in thin down version of BTS, BSC and MSC of GSM infrastructure, the power consumption is of the order of few KW, and there is requirement of air conditioner, battery backup and diesel generator , all in 1+1 configuration This makes the cost of GSM infrastructure very high). Wireless LAN, following 802.11b (10 Mbps DSSS) RF technology known as WiFi Access Points (AP) and Hotspots have mushroomed, both for indoor and outdoor applications. These nodes cater for voice (VoIP) traffic also, hence the telecom network for villages can be easily be set up, based on VoIP and WiFi technology. This concept of VoIP voice using WiFi network is nothing new. For example, (a) many corporate houses have branch offices VoIP exchanges for intercom and the employees use their laptops or pcs on wired and wireless LAN, or VoIP WiFi phones or tablet pcs or smart phones for their internal communication, without paying for telecom service providers. Via their VPN, they connect to Head Office also. (b) Large University campuses use mix of indoor and outdoor WLANS for voice and Internet traffic. (c) During disaster situations, using solar powered WiFi nodes, quick voice and Internet access is provided. During Prime Minister’s visit to California (USA) (i) Microsoft proposed solar powered tethered balloon WiFi nodes for voice / Internet access for large rural areas. (ii) Google proposed high towers with high bandwidth WiFi aps along the railway lines for Internet access to passengers. The Google proposal for high bandwidth, high power Ap’s at few 10s kms away is OK for the passenger comfort of accessing Internet, e mail , etc. but the tethered balloon for village is an expensive proposal with maintenance problems, for handling low voice (VoIP) and data traffic from typical small village. BSNL themselves have introduced“ BSNL Wings” service, which caters for any VoIP traffic from any IP network service provider, to access any PSTN number at a nominal subscription. It will use the centralized VoIP PSTN Gateway router provided by BSNL to get on to PSTN network. This paper examines how to cater for voice traffic in villages or rural areas, using VoIP in smart phones and outdoor WiFi technology. The villager can use cheapest smart phone, which caters for WiFi access also and not use the GSM route. Network of minimum number of weather proof and water proof, low bandwidth (11 Mbps), solar powered WiFi aps on high masts is all the infrastructure required for local traffic. For traffic outside the area, VoIP to PSTN router will be provided at the central node, with or without VSAT terminals, depending upon whether PSTN connectivity is available locally or not.

a) Problem Definition:

• Infrastructure cost is very high at the order of 1 to 1.5 crore (even in thin version of GSM network)..
• Non availability of prime power is also major handicap for the GSM service provider. If power of the order of about 3 Kw for a BTS has to be managed by solar power with battery backup, the cost will become prohibitively high.

• Hence, Return on Investment (ROI) is not attractive for a GSM service provider to cater to, essentially thin voice traffic requirement in a typical village or rural area.

b) Proposed Solution

Alternate and cost effective solution (roughly at one tenth or lesser cost), using Internet technology and using solar power is possible for the infrastructure required for voice traffic in villages. Cost reduction of infrastructure is due to use of low cost outdoor WiFi nodes. During the last 2 to 3 decades, because of large number of Internet user requirements, the cost of computer networking products have come down drastically. At the cost of copper based 10 Mbps Ethernet LAN few decades before, today one can get fiber based gigabit bandwidth LAN. Same is the case with wireless LAN, bridges, routers, brouthers, switches of IP network, whose cost have come down drastically over the last few years.

II. DESIGN OF THE PROPOSED SOLUTION

A) This solution caters for a typical village level voice communication facility:

- Typical village size – 12 Sq Km (2 Km radius). Nearly flat terrain. Scattered few buildings, not more than 5 to 7 m height.
- Number of users with low cost smart phone with WiFi – about 1000.
- Number of simultaneous voice calls during busy hour, within the village – about 25 two way (50 users).
- Number of calls to outside the village, using PSTN gateway – about 10.
- Traffic and bandwidth requirement : Qty 50 * 9.6 /64 kbps voice traffic, housekeeping traffic between WiFi Access nodes and WiFi router (if central router is used for controlling WiFi nodes) , SIP server/client housekeeping traffic, PSTN gateway router etc – within typical minimum bandwidth of commercially available WiFi Access nodes which is about 11 Mbps.

B) Design aspects

I) RF propagation aspects:

(a) Path loss between WiFi nodes:
LOS path loss for 2.4 Ghz and 2 Km distance: ~ 106 db
EIRP of WiFi node = 26 dbm + 5 db omni antenna gain ~ 30 dbm
Rx power @ 2 Km LOS = - 76 dbm. Thermal noise: (KTBF) @ 10 Mhz b/w and 3 db Noise figure of front end of Rx = ~ - 101 dbm.

Enough (25 db) C/N for this low data rate of voice for which even BER of 10 power -3 or -4 will do. With obstructed LOS and multi path fading, can easily give about 1.5 Km range between WiFi nodes. With DSSS modulation and its coding gain, C/I is also acceptable for 10 power -3 or -4 voice quality.

(b) From smart phone to nearest WiFi node:
Effective Isotropic Radiated Power (EIRP) of smart phone (2.4 Ghz band) = 300 mw = 24.7 dbm
Path Loss at 1.25 Km: 32.45 + 20 log (2400 Mhz) + 20 log (1.25 Km) = 102 db

Received power = 24.7 – 102 = - 77.3 dbm.
With 7 to 10 m tower at WiFi node, this range of 1.25 Km is possible. Hence 4 WiFi nodes can easily cover 10 to 12 Sq Km of the village, and give reliable service, even if there are some obstructions between nodes. To be on safer side, cater for 8 WiFi nodes, with at least one node having routing feature (if centralized routing is required for the aps). Limited field trials with few target aps ( tp link tl-wa 5210g) with high gain omni antenna (tp link tl-ant 2415d, ground mounted) and low cost android smart phones was carried out. The range obtained was lesser, since the eirp of ap was lesser than specs. Same is the case in respect of locally available low cost android smart phones. Range obtained will improve with 10m high mast for mounting ap and solar panel with rechargable battery backup. For budgetory purposes, to be on the safe side, 16 aps (with about 20% overlap) has been considered and budgetory cost all infrastructure for a village arrived at. Customers can use affordable Smartphones (without frills of cameras, games and other apps and use WiFi route instead of GSM route). Cost of inexpensive smart phone is about Rs 7000. Alternately, VoIP phone with WiFi or Tablet PC with WiFi can be used at about the same cost.

C) VoIP and WiFi AP aspects:

Basic voice channel 64 kbps G 711 PCM (or G729 9.6 kbps). Testing can be done with 64 Kbps [8,9 ]. Allowing for IP framing and call set up / tear down over heads, one voice channel can be taken as 100 Kbps. This caters for Distributed Inter Frame Spacing (DIFS), additional back off, Data Frame (Flag, Address, Control, Data, FCS, CRC if used etc), Short Inter Frame Spacing (SIFS), ACK frame, as in typical WiFi handling of IP frames. If we choose a 10 Mbps speed for WiFi AP, it should support about 50 one way or 25 Rx and Tx frames from source to destination, since from WiFi node point of view, it receives IP frame from sending node and transmit it to receiving node. Hence double bandwidth is used. Hence capacity will be 50 simplex or 25 duplex voice channels. Distributed over 8 WiFi nodes in the network, average load on WiFi during busy hour is 3 to 4 duplex voice calls.

D) Optimization for achieving maximum number of simultaneous VoIP channels via one 10 mhz 802.11b WiFi AP [2, 4, 5, 6]:

A) VoIP aspects:

1. Use of G711 (64 Kbps) or G 729 (9.6 Kbps) voice coding. The simulation study to assess the performance of the ap has been done with 64 kbps voice, since the performance will be better at lower coding rates.

2. VoIP payload per IP frame – as large as possible – 100 msec payload @ 64 kbps it will be 800 bytes which can be accommodated in V4 IP also.

(b) WiFi AP and IP frame aspects:

1. Exclusive WiFi AP for 10 Mhz 802.11b VoIP traffic handling with bridging, relay and routing functions as required in each node. [8,9]

2. Preferably self-managed AP to conserve bandwidth for centralized routing management traffic.

3. Since it is exclusive VoIP traffic, no back off or guard time between IP frames.

4. IP frame buffer size – as minimum as possible.
5. Minimum inter frame spacing.
6. Star and mesh configuration will be adopted, so that at most, only 3 or 4 aps will be involved for voice traffic handling from source to destination VoIP clients.
7. No rigid specifications on QOS, latency, packet loss, packet delay, jitter etc. So long as reasonable voice quality is obtained between smart phones it is adequate.
8. The number of VoIP channels which can be handled by an AP will depend on the voice channel payload per IP frame (sampling size Row in msec units), voice coding rate C in Kbps, and physical data rate of RF L in Mbps.

- The expression for number of channels (NC) is given by equation
  \[ Nc = \left[ 500 \times \text{Row} \right] / \left[ 774 + (592 + C \times \text{Row}/L) \right] \]
- Adopting Row = 100 (msec), C = 64 and L = 10,
- We get 30 to 35 channel capacity for 64 Kbps voice, payload per IP frame 100 msec or 800 bytes and RF Tx rate of 10 Mbps.

III. PROPOSED IMPLEMENTATION - SIMULATION STUDY

To verify point D) b (8) above, it is intended to carry out a simulation study. The simulation s/w is to use 2 Physical Laptops with Laptop A as the source and Laptop B as the destination, for sending and receiving, simultaneously up to 50 encoded voice channel packets in interleaved manner, (as if emanating from up to 50 smart phones simultaneously), using a 10Mbps WiFi (802.11 b) RF link from Laptop A to Laptop B (simplex mode). Using sipp simulator or as simple C code and socket level programming, 64 kbps (G 711) encoded voice packets are prepared apriori, for 50 voice channels and sent as IP, UDP, SIP frames in interleaved manner, to simulate multiple simultaneous voice calls from smart phones to an exclusive 10 Mbps 802.11 b WiFi AP. At the receiving end, the data packet addresses are seen and saved as respective voice files, corresponding to sending address of voice channel file. The decoded voice is checked for quality. The number of voice channels handled in the link is gradually increased in steps of 10, to check up to how many simultaneous 64 Kbps voice is handled by the 10 Mbps WiFi AP for satisfactory quality.

IV. PHYSICAL IMPLEMENTATION DETAILS

Location of AP nodes will take into account ground topology, likely users locations etc. 7 to 10 meter high mast will be used to house WiFi AP and solar panels with battery backup. This will cater for near LOS between aps and from and to smart phones to the nearest AP. Figure 1 shows the topology for covering an area of 10 to 12 km, a simple star configuration of 4 WiFi nodes mounted on 7 to 10 m mast, along with solar panel and battery backup, will be sufficient as shown in the schematic diagram and as per the propagation aspects, mentioned earlier, between AP nodes and between an AP node and smart phones in that area. The exact location of the WiFi nodes will be decided after field study of the exact area, avoiding obstructions, any high rise building etc. If the site survey indicates some pockets not well served by the nearest AP, few more aps will be added. A Windows based PC / Laptop at central AP will cater for SIP server s/w and also support VoIP to PSTN gateway router on LAN. Figure 2a and 2b shows Central node with PSTN connectivity using VoIP to PSTN router and when PSTN connectivity is not locally available respectively.

V. APPLICATIONS

Villagers are small farm holders and they do not require Internet for marketing perspective. [10] Experiences in using WiFi for Rural Internet in India” (Digital Gangetic Plains DGP)80% 0f villagers are of small farm holding type, and produce only few 100 Kg in a year. They do not require high bandwidth Internet to market their produce to the other end of the world. Hence from marketing perspective, they do
not require Internet support. On the other hand, Govt machinery already exists to collect their produce at site and pay them on the spot. They even take care of soil testing at the nearest lab, and advise them on correct manure for their farm. Hence Internet availability to 80 % of villagers in lakhs of villages with expensive fiber optic backbone network is waste. 

* For setting up VoIP calls between smart phone clients, one can use one PC / Laptop running SIP server software, (which is easily available in open source ( Asterisk, officesip etc) in one node in the WiFi network. Hence for VoIP calls, between smart phone clients, one need not go outside the network, like using whatsapp or skype etc via internet.

* Students of higher class can benefit by Internet access. In this connection, these points are relevant.

* The performance of WiFi AP comes down drastically, if required to handle both real time IP UDP frame having VoIP payload and IP frame for data traffic.

* This problem can be solved by having different 11 Mhz freq slots in the 802.11 b band, one for VoIP call traffic and another for IP traffic.

* Most of the aps will handle VoIP calls.

* One or two aps will carry IP traffic for Internet access by students.

* From security and unwanted access of Internet for movie or pronography, only the students end nodes to be registered with the AP for IP traffic.

* Automatic filtering of sites, manual supervision, and limited time availability of these 2 APs carrying IP traffic is recommended.

* The IP nodes will cater for other data traffic from Telemedicine, any new IOT etc traffic.

* For Distance Education, use only TV Receive mode to receive broadcast from Distance Education hub.

* For integration of VoIP and PSTN network various options exist, BSNL Wings service, one VoIP PSTN Gateway router in one of the villages etc.

* For WAN, small size VSAT (Ku, Ka band) VSAT nodes with solar power are proposed.

VI. CONCLUSION

VoIP from low cost smart phones and WiFi mode, and using solar powered, low bandwidth ( 11 Mbps) outdoor WiFi aps, in 2.4 Ghz (license free ISM band) as the infrastructure will be taken up as a pilot project , as a cost effective alternative to very expensive and power hungry GSM infrastructure. Gateway to other networks, using VoIP to PSTN router will be catered for, from a central node. If PSTN is not available locally, Qty 2, 4 analog voice channel capacity VSAT will be used to reach the PSTN location. A network of outdoor, water proof, weather proof, low bandwidth ( 11 / 54 Mbps 802.11 b/g) solar powered WiFi aps with high gain ( 10 to 15 Db) omni antenna is proposed for village network, to cater for VoIP voice from low cost smart phones of the farmer class villagers and for Internet facility for students. The above is based on calculations for distance between cheap smart phones and the AP and between aps, and also Proof of Concept ( poc) field trials carried out by RV College of Engineering. For wide area network, Ku / Ka band VSAT nodes with one Ethernet port (RJ 45) is enough.

The Bill of Materials (BOM) including solar power with rechargeable battery, small mast, VSAT node has been worked out. The budgetary cost for village of about 10 Sq Km ( 1.75 Km radius) with about 5000 smart phone users and few students for Internet traffic is estimated to be about Rs 15 to 20 Lakhs only.

A simulation study software and experimental verification with a target AP, to ascertain how many VoIP calls can be supported by one nearest AP, (under roaming conditions) has also been done. It is only required for any major public / private firm(s) to deploy in few villages as actual field trials. On successful completion of this pilot project, this network can be replicated in as many villages as required.

V. REFERENCES:


[2]. Nghia T. Dao, Xun Wei, Robert A. Malaney The Voice Capacity of WiFi for Best Effort and Prioritized Traffic pp 1-6

[3]. Bin Hong Lee, Guan Yan Cai1 Yu Ge, Winston K.G. Seah, VoIP Capacity over Wireless Mesh Networks,


[9]. Patrick Verkaik, Yuvraj Agarwal, Rajesh Gupta, and Alex C. Snoeren, Softspeak: Making VoIP Play Well in Existing 802.11 Deployments” University of California, San Diego NSDI’09 Proceedings of the 6th USENIX symposium on Networked systems design and implementation pp 409-422

[10]. Bhaskaran Raman and Kameswari Chebrolu, Experience in Using WiFi for Rural Internet in India”, IEEE Communications Magazine • January 2007, pp 104-110
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