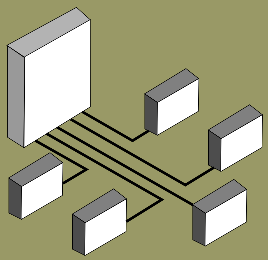
Can 3G technologies benefit Rural India ?



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ABSTRACT

To increase telecom penetration into rural India, we would need low cost options for networks and devices that provide support not only for voice services, but also for rich media and higher data rate services. In this paper, we examine whether the evolution of GSM into 3G and HSDPA could enable this transformation, since this provides higher peak data rates and also significantly increases the network capacity. The problem is that 3G devices and services are typically part of the premium (high-price) services in the developed countries, while they have to be offered at very affordable prices if they have to take off in the rural areas. A paradigm shift may thus be required to resolve this paradox. In this paper, we examine if low cost 3G and HSDPA is really feasible.

INTRODUCTION AND CONTEXT

India has seen a rapid increase in wireless coverage. GSM and CDMA are the competing technologies. As of July 2005, the wireless penetration at 59.83 million is significantly higher than landline penetration, which is at 47.17 million. The overall tele-density is around 9.86% [1]. The monthly cellular additions are getting closer to 3 million/month, with GSM technology base having a higher subscriber base accounting for about 80%. The bad news is that the gap between rural tele-density (1.74%) and urban tele-density (26.2%) has been widening, perhaps because per capita rural GDP of 352$ is a fourth of urban GDP [2]. This is unacceptable since 72% of India is rural. However, there is a strong push to increase cellular coverage in the rural areas, and the Government of India has set targets as shown below primarily for voice services [3]

	BY AREA		BY POPULATION	
	2004	2006	2004	2006
TOWNS	~1700 of ~5200	~4900 of ~5200	~200 Million	~300 Million
RURAL AREAS	Negligible	~350,000 of ~607,000	Negligible	~450 Million

Besides network coverage, the other evolution of relevance is the new product segment called "ultra low cost (ULC)" handset driven primarily by demand from countries like India, China and Russia. The ULC phone carries a monochrome LCD display with no graphics capability, and is primarily targeted for voice communication with support for SMS. Since it is unlikely that messaging will take off due to low literacy rates, the usage of the ULC phone in the rural areas will probably be limited to voice conversations alone.

On the other hand, the rapid spread of television content in rural India shows us that audio-visual content can be easily absorbed by the rural masses. Delivery of such "rich media" requires bandwidth that is clearly not supported by existing 2/2.5G cellular services or even by early 3G services it needs deployment of evolved technologies like HSDPA. However, HSDPA is expensive primarily because it is viewed as a high revenue opportunity in the western world. In fact, as we shall discuss in this paper, the incremental cost of delivering bandwidth using HSDPA to specific places is not actually that high. The key problem with HSDPA is range - providing high bandwidth universal access over a large area using HSDPA could prove to be expensive.

To circumvent this, we note the following two points

- In the rural areas, only certain types of services can be delivered directly to the end user. The World Bank in an unpublished study identified radio, TV, loud speakers, poster boards and to an extent telephony as services that can be delivered without any mediation. On the other hand, more sophisticated content like those available on the internet may have to be delivered only through an intermediary such as a postman, a rural health worker, a teacher or a kiosk operator.
- Full mobility may not really be required in rural areas. The key value of wireless is in its ability to offer "untethered" communication, so that we can dispense with costly wires. In terms of services, untethered wireless could be used to deliver services at low cost kiosks and at mobile-van stops. These kiosks and mobile vans could provide several non real-time services as well, which do not need any connectivity.

Thus there could be intermediate solutions, if we focus on providing high bandwidth connectivity only at designated points using HSDPA.

THE GSM ADVANTAGE

It may not be readily evident that the bottleneck in rolling out services to rural areas is not the cost of electronic equipment, but is actually due to the following

- The most significant cost component is the site preparation and the erection of the tower. Infrastructure like roads and electricity may have to be first set up. The towers are about 40 m tall, and require considerable amounts of expensive steel.
- The second highest contributor to the cost is the power infrastructure RF cables running to the top of the tower, the power amplifiers, RF filtering and the transceivers. Roughly 55% of the cost of the base station equipment is in these RF components [9].
- The maintenance of cell site infrastructure requires local personnel who should be trained to deal with the problems that arise in wireless equipment.
- The availability of ULC phones at costs below Rs 1500 (US$ 35) and financing packages to purchase these.
- Proper distribution infrastructure for phones, SIMs, spares and accessories in the remotest areas, and the availability of rudimentary training to users so that they can use the phones properly.
- Billing and collection infrastructure for pre and post paid subscribers.

If we accept these as the real bottleneck, then it is immediately evident that once we have sufficient GSM voice coverage across India, we are already past the key hurdles the cell sites and towers are set up, the maintenance, distribution, user training and billing/collection infrastructure are all in place.

We first argue that it makes economic sense to deploy 3G just for voice. For this, we need to determine the incremental the incremental cost of a 3G handset and the incremental cell site infrastructure costs to deploy 3G. The latter requires a careful comparison of GSM and 3G systems from the point of view of voice capacity.

COMPARISON OF GSM AND 3G VOICE CAPACITY

It is not easy to compare the capacity of GSM systems with that of 3G systems as they are based on different principles. However, if we intend to replace one with the other, we have to make an estimate of the 3G equipment that will be required to support the same number of voice calls served by an existing GSM system.

- 3G systems use WCDMA that requires a minimum of 5 MHz of bandwidth each for uplink and downlink that supports over 60 simultaneous voice calls, while GSM requires only 200 KHz each way to support 8 simultaneous calls.
- In GSM, interference from neighbouring cells can significantly affect the performance. Consequently, frequency planning is used to ensure that a frequency band used in a cell is re-used only in cells that are spaced sufficiently far away. A re-use factor of 7 means that the frequency in a cell is different from the six cells that surrounds it. Since 3G systems are based on CDMA technology that can deal with interference, neighbouring cells can share the same frequency. 3G also uses advanced coding and modulation methods.
- However, GSM technology has been continuously improving over the years in interference management. In particular, the use of cell sectorization reduces interference significantly. Cells with 3 sectors are typical, while a higher number of sectors (6 or higher) could also be deployed. Use of discontinuous transmission (transmission is suspended when there is no voice activity) and slow frequency hopping allows interference between cells to be reduced. Adaptive (intelligent) antenna arrays could also be used to direct the transmission power towards the active users. All the above allow the re-use factor to be reduced even to 1. By using adaptive multi rate (AMR) codecs, the quality of voice can be improved especially at larger distances. Finally, by using half rate AMR, the capacity of a GSM cell could be doubled.

Assuming 2% grade of service, with these advances GSM can provide a voice spectral efficiency of 13-33 Erlangs/5MHz/sector [10] while 3G using WCDMA can provide 52-83 Erlangs/5MHz/sector [11]. This means that 3G offers a voice capacity increase of 2-3 times over GSM.

MIGRATING TO 3G FOR VOICE

To deploy 3G at a cell site, Node B equipment has to be installed (instead of or in addition to the GSM BTS equipment). The cost of such Node B equipment has been falling by approximately 40% each year over the last 4 years. Taken together with the fact that 3G offers more capacity than GSM, the 3G Node B is just 50% more expensive today than the GSM BTS to deploy the same voice capacity [9].

We have already seen that 55% of the cost of base station equipment is in the RF. Since a single 3G channel of 5 MHz replaces many GSM channels of 200 KHz required achieving the same capacity the RF costs of 3G systems should over time be lower than that of GSM systems. Does this mean that 3G will eventually lead to cheaper equipment than GSM?

The issue with 3G is scalability. In 3G, capacity can only be deployed in large chunks voice call demand has to be about 60 erlangs per sector for the capacity provided by one carrier to be effectively utilised. On the other hand in GSM, capacity can be deployed in smaller chunks since the smallest carrier is 200 KHz supporting 8 simultaneous calls. The opportunity to migrate to 3G thus arises only when the GSM system capacity starts to fill up. The ideal system is thus a combination of GSM and 3G. We start building up capacity using GSM once the capacity per sector nears 60 Erlangs, we can migrate that cell site to 3G.

What about handsets? If we don't consider the multimedia applications and costly peripherals typically present in 3G handsets, then the only difference between 3G and 2G is in the baseband and RF silicon. As we know very well, silicon costs diminish rapidly over a period of time. Looking at pricing trends for 3G silicon, ULC 3G handsets should be available at price points below Rs. 2200 (US$ 50) in 2-3 years, excluding royalty costs.

Thus it makes economic sense for an operator to deploy 3G just for voice, even at the low price points set by existing GSM operations in rural areas. We now look at data services.

3G FOR DATA SERVICES

Once 3G systems are deployed, they are already able to offer some rudimentary data services that require up to 100 Kbps to near line of sight terminals at distances of up to 5 Km. For example, a phone equipped with video telephony application based on the H.324M standard can operate a data rate of 64 Kbps, and such phones could be available for price points below Rs. 3500 (US$80) in 2008. Thus, we could support some "rich media" services at marginally higher monthly subscription rates.

However, good quality audio-video delivery requires 512 Kbps data rates, which is not possible using 3G.

UPGRADING 3G TO HSDPA

To enable availability of innovative services with rich visual content, operators must deploy evolved 3G technologies like HSDPA (High Speed Downlink Packet Access). HSDPA has several advantages

- **Increased bandwidth**: HSDPA offers over 7X peak data rates, up to a theoretical max of 14Mbps.
- **Increased network capacity**: Over 4 times existing capacity, through better spectral efficiency and advanced modulation schemes (16 QAM). It is also reuse efficient, with a reuse factor of 1.
- **Reduced Round-Trip-Time**: Incremental redundancy and Hybrid ARQ at the Layer 1-Layer 2 level reduces RTT, as against convention ARQ, implemented in the IP Layer.
- **Favourable allocation of resources**: Network schedules grants based on mobiles that are active in the cell.

The net effect is to increase the average capacity of the system and to improve the service performance experienced by individual users. Using HSDPA, the expectation is that the cost to deliver a 10Mbyte file can be brought down to one-fifteenth the amount that it would take via GPRS and one-fifth via UMTS Release 99 [4].

HSDPA is realised by a downlink channel (HS-DSCH) shared between terminals by allocation of individual codes, from a common pool of codes assigned for the channel. The HS-DSCH is associated with one downlink DPCH, and one or several Shared Control Channels (HS-SCCH). The HS-DSCH is transmitted over the entire cell or over only part of the cell using e.g. beam-forming antennas. The HS-SCCH is a fixed rate (60 kbps, SF=128) downlink physical channel used to carry downlink signaling related to HS-DSCH transmission. The High Speed Physical Downlink Shared Channel (HS- PDSCH) is used to carry the High Speed Downlink Shared Channel (HS-DSCH). A HS-PDSCH corresponds to one channelisation code of fixed spreading factor SF=16 from the set of channelization codes reserved for HS-DSCH transmission. Multi-code transmission is allowed, which translates to the terminal being assigned multiple channelisation codes in the same HS-PDSCH sub-frame, depending on the terminal capability. An HS-PDSCH may use QPSK or 16QAM modulation.

The following table captures the key parameters of HSDPA, compared with GSM/GPRS

Feature	GSM/GPRS	HSDPA
Multiple Access Scheme	TDMA	CDMA
Modulation Schemes	GMSK, 8-PSK(EDGE)	QPSK, 16-QAM
Signal Bandwidth	200 kHz	3.84 Mhz
Channel Symbol Rate	270.833 ks/s	3.84 Ms/s
Maximum output Power [dBm]	30 to 33	24 to 33
Minimum input Power [dBm]	86 to 104	103 to 106
Range	35 Km	2 Km
Channel Coding	Block and Convolutional	Convolutional and Turbo

Modulation format	Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/ HS-DSCH subframe
QPSK	480	240	16	960
16QAM	960	240	16	1920

HSDPA: RANGE IS THE CHALLENGE

As can be seen in the above table, the range of HSDPA is severely limited to around 2Km cells, as compared the current GSM/GPRS systems that have range that is one order of magnitude higher. This could mean that the current GSM/GPRS infrastructure is largely insufficient for HSDPA coverage, and significant additional capex may be required to deploy HSDPA into rural areas. The entire cost benefit gains of HSDPA due to its higher capacity could thus be offset due to the cost increase due to lower range.

Range is dependent on some key factors as discussed below

- **Frequency:** Lower frequencies reach further. But it is highly unlikely that bandwidth in the 400 MHz bands will be made available for HSDPA in India.

- **Data rate:** Lower rate transmissions can span a higher range. A 100Mbps transmission can be coherently received over 200 metres, while for distances in kilometres, only 100 kbps transmission per subscriber may be realisable. This may limit the kind of services that can be provided.

- **Position of the terminal antenna:** Rooftop antennae can provide a range of around 30 kms [5]. The table below summarises this. Such antennas are already in use for example in the CorDect systems in India [6]. This could lead to innovative solutions of accessing HSDPA only at designated "sockets" (at Kiosks or at designated mobile van stops). This should also solve the otherwise nightmarish problem of terrain planning. Voice coverage can continue without any change.

- Using repeaters especially in rural areas, the range can be increased without substantially increasing the cost. This is an active part of Release 6 recommendations [7].

	Gain	Height	Building Loss	Range	Relative site count
Rooftop- LOS	10 dBi	8 m	0 dB	> 30 km	
Rooftop NLOS	10 dBi	8 m	0 dB	6.2 km	1
Terminal- upstairs window	3 dBi	5 m	0 dB	1.8 km	12
Outdoor Pccard	0 dBi	1.5 m	0 dB	780 m	60
Indoor PCcard- Suburban	0 dBi	1.5 m	10 dB	410 m	230
Indoor PCcard- urban	0 dBi	1.5 m	20 dB	210 m	800

All figures except LOS based on COST231-Hata model with 10dB shadow margin and no cable losses. System operates at 2GHz with 1Mb/s from 24dBm EIRP terminal TX, 3dB Eb/No, 5dB NF RX. BS antenna= 18dBi Source:[5]

Increasing the range of HSDPA is a key research problem that determines its success for rural India.

INCREMENTAL COST OF HSDPA

The assumptions we make are as follows

- Subscribers are dispersed. GSM coverage enables quick and easy 3G and HSDPA access.

- Peak and average bandwidth requirements are the same - there are no "busy hour" traffic profiles.

- Bandwidth usage per session is high due to rich media services. However, number of sessions per subscriber per day is low. Many more subscribers thus share the higher network capacity.

- Since the data services delivered to rural users needs to be mediated, it may be sufficient to provide high bandwidth connectivity only at designated access points. Intermediation also leads to more effective sharing of available network capacity. A kiosk or a mobile van can be equipped with an external antenna, thus allowing HSDPA to be delivered over larger distances. The cost of the external antenna and the cabling could discourage general users, but should be attractive to kiosk owners and mobile van operators.

Since India has not yet made any moves on 3G, it makes sense for India to directly leapfrog to HSDPA. The difference between HSDPA and 3G is only in the baseband subsystem, which contributes to only 15% of the cost of the base station [9]. Thus, the incremental cost of deploying HSDPA is not likely to be more than 10%.

RICH MEDIA SERVICES ON A FAT PIPE VIA THE CELLULAR NETWORK

Once HSDPA is deployed, it is possible to offer rich media services. Some developments in this direction are

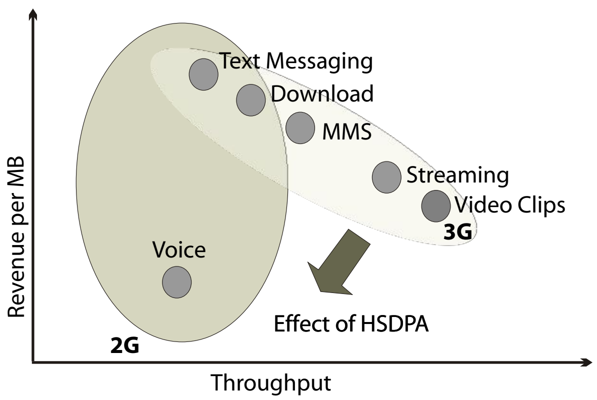
- MBMS is a unidirectional point to multipoint bearer service [8]. Services like streaming video and audio can be supported on MBMS. MBMS has been standardized as part of UMTS release 6, and should see deployments in 2008. Rich Media services like MMS can use the MBMS bearer. The new MPEG-4 AVC Baseline (H.264/AVC, Advanced Video Coding) is currently being favoured in the standards for Release 6.

- Another innovative media delivery system taking shape is IMG (Internet Media Guides), which provides details of content like Television clips, etc. The entire IMG infrastructure can be deployed over HSDPA. An IMG browser application provides a window into the available media content. The user selects the content he desires to view. This is then viewed using another application (codec/ media player etc).

- For digital TV content, the DVB standards are more suited to mobile terminals. Integration of DVB into UMTS is being studied. Some of the key features of DVB-H are time-slicing, 4K-FFT and FEC. DVB-H employs a mechanism where bursts of data are received at a time so that the receiver can save power. Using the 4K mode with some 3409 active carriers, DVB-H benefits from the compromise between the high-speed small-area SFN capability of 2K DVB-T and the lower speed but larger area SFN of 8K DVB-T.

PRICING HSDPA SERVICES

The key to enabling the proliferation of 3G and HSDPA based services in the rural areas is to get the pricing right. Currently, streaming, downloads, video clips etc are high-bandwidth and high-revenue opportunity for 3G operators in the western markets, as shown in the figure below. The introduction of higher capacity through HSDPA at marginal costs provides an opportunity to offer rich media services at much more affordable prices. High reliability and lower RTT increases the effective bandwidth available and should in turn have a cascading effect on the cost. New services shown in the box below should become available once the costs start falling.



SERVICES FOR RURAL AREAS

- Mobile Crop Auctions
- Commodity Futures
- Game Score updates
- Weather forecasts
- News
- Advertisements
- e-Coupons
- Micro-credit
- Tele-medicine

COMPARISON WITH OTHER OPTIONS FOR A FAT DATA PIPE FOR RURAL INDIA

Since there is no copper laid out in rural India, DSL is not an option to deliver high bandwidth services. Given the existing and potential coverage realised by GSM/GPRS cellular systems, the incremental cost of implementing HSDPA should be much lower than that of setting up any other green field wireless network. In particular, it can be argued that for the same coverage, HSDPA with advanced network planning can replace around 1000 Access Points of W-LAN. WiMax could be a challenger, but its maturity is currently much lower than HSDPA, and WiMax could have similar challenges for higher range transmissions.

CONCLUSION

While the tele-density in India is increasing rapidly, the growth is primarily in the urban areas. Expanding the telecom penetration into rural India requires both voice and rich media services to be delivered at affordable costs. We explain how 3G deployments are already cost effective for voice services, as they can directly leverage the significant infrastructure that has been laid out for GSM. Since India has not yet made any concrete decisions on 3G licensing, it makes sense for us to leapfrog directly to HSDPA, which allows delivery of rich media services. The problem with HSDPA is its limited range when compared to GSM. This can be circumvented by delivering HSDPA based services at designated points like kiosks and mobile van stops which can afford to use external antennas to get extra range. This also fits very well with the delivery method that may have to be used in the rural areas, where services are delivered through trained personnel like postmen, health workers, teachers or kiosk operators.

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