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A low-cost Connected TV platform for Emerging Markets – Requirement Analysis through User Study

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Abstract — This paper introduces a low-cost internet connected device that uses television as a display with a focus on emerging markets. The emerging markets are characterized by extreme cost-consciousness of the users. To this end, the paper proposes an end-to-end solution that is realized as a set top box working as an over-the-top device to the existing television set designed with a low-cost low-computing power processor with multimedia accelerators and with open-source software. The solution has applications like multimedia content playback, internet surfing, video chatting, and SMS to address the needs of the target user segment. The paper introduces a novel multimedia framework for applications deployment and describes the applications. Finally the results of a user study conducted with an actual implementation of the device are presented and the results are analyzed to give insights into the market needs and mapping into technical requirements.

Keywords – connected television, interactive television, internet on TV

I. INTRODUCTION

As we embrace the ubiquitous computing technology [1], there is a visible trend all across the world of moving from Personal Computer (PC) towards mobile phones, tablets and TVs as the preferred set of ubiquitous screens in our life [2]. However, market studies in India reveal some interesting facts. According studies by Indian Marketing Research Bureau (IMRB) [3], in 2009 there was 87 Million PC literate people in India (out of 818 Million total population above age group of 12) and 63 Million internet users of which only 30% of these users accessed internet from home PCs. There were a sizeable 37% of users accessing the internet from cyber cafes and only 4% accessing from alternate devices like mobiles. More recent studies by International Telecommunication Union (ITU) indicate [4] that in 2010, household computer penetration in India was only 6.1% and household internet penetration was only 4.2%. This clearly brings out a clear picture of the digital divide that exists in India, where very little proportion of the population have access to PCs or Internet due to cost, skill, usability and other issues. [4] and [5] indicates that there are about 812 Million mobile subscribers in 2011 (mobile phone penetration above 60%). However, [5] also states that only 26.3 Million of these users are active mobile internet users. Similar kind of digital divide pictures emerge from other developing countries also [6], [7].

In order to analyze the above market information, we need to recognize that there are three basic screens with which users normally interact – Personal Computer / Laptop / Tablets, Television and Mobile Phone / Smart Phones. Looking from the India and developing country perspective, Personal Computer / Laptop / Tablets are still not quite affordable to masses. Personal Computers / Laptops also suffer from usability problems for non-techno-savvy users, mainly represented by the older generation. Mobile Phones, though cheap and affordable, suffer from its very small display screen real-estate, which prevents detailed information dissemination and rendering on the screen. Smart Phones and Tablets do have larger screens but their cost is quite high for mass adoption.

On the contrary, analog Television is a pervasive device that has invaded most of the homes. Number of television sets used in India has reached more than 60% of homes (158 Million households in 2011 - http://en.wikipedia.org/wiki/Television_in_India). In this context, if we could make the Television Connected to the Internet-world in a low-cost manner, it has the potential of becoming the "Ubiquitous Computing Screen" for the home helping in bringing down the above-mentioned digital divide having the following three advantages –

- Large-screen real estate to disseminate and render rich information
- Low-cost, thereby being affordable to the masses
- Simple user interface using TV-like remote control, thereby addressing the non-techno-savvy user needs

Connected Televisions are already making their mark in the developed countries (http://www.informationweek.com/news/personal-tech/home-entertainment/219100136). There are connected TV / Smart TV solutions from LG, Samsung, Vizio, Sony, Panasonic etc.

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[8]. In [9], we get specific details about Smart TV market potential in Korea and in [10], the concept of providing social applications on Smart TV in introduced.

However, the emerging markets like India are characterized by extreme cost-consciousness of the users which not specifically addressed in these solutions. Also, most of the connected TV solutions require buying of a new TV, which may not be good option in many Indian households – they would like to make their existing TV connected. Hence, there is need for a low-cost add-on device to analog Television (as an over-the-top box) which turns it into a connected TV – this paper tries to propose such a solution. Also to find out the expectations of the users and deployment constraints, it is needed to conduct a user study on the proposed solution and analyze the results to ratify the requirements and to look for new requirements. Such an analysis is also presented in the paper.

In this paper with present the proposed system with hardware/software architecture, framework and applications in the "Proposed System" section. Then "User Trial" section, we describe the user study configurations and results of the study. Finally in the "Requirement Analysis" section, we analyze the results of the user study and derive requirements for the next version of the solution.

II. PROPOSED SYSTEM

A. *Sytem Description*

The system proposes the use of an affordable over-the-top (OTT) box called Home Infotainment Platform (HIP) that can connect to internet and has TV as the display. To keep the box cost low, it uses a low-cost low-computing power processor with multimedia accelerators and tries to use a lot of open-source software. There are applications for audio/video/image playback, internet surfing, video chatting and SMS on the box. As the wire-line broadband has not reached to all parts of the country, the device uses market-available GPRS/CDMA USB modems for connectivity. In order to ease the application development effort, the platform introduces a novel multimedia application framework on ARM that is tightly

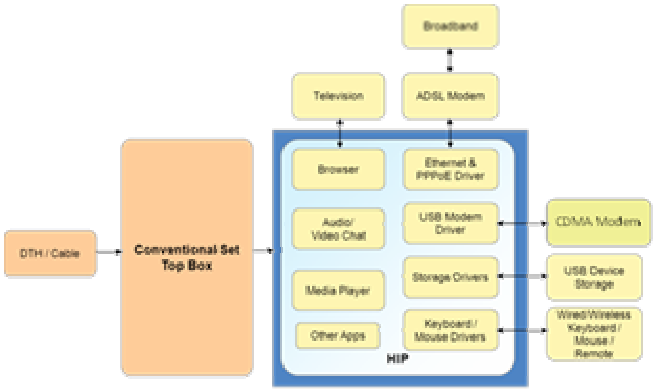

Figure 1. Home Infotainment Platform System Block Diagram

integrated to the DSP accelerator. It is an information and communication platform that provides consumers with basic computer functionalities (information access, entertainment and collaboration) on a television set. Figure 1 describes the system blocks and its interfaces.

Processor family, RAM and Flash size are chosen keeping the application requirement in mind while optimizing cost/performance ratio. The interfaces are decided based on application requirements. After careful analysis of all the requirements, cost and availability, the final hardware configuration was chosen as below -

Processor - Texas Instrument's DaVinci DM 6446 with dual core (300 MHz ARM 9 with 600 MHz 64x DSP)
RAM – 256 MB
Flash – 128 MB
USB 2.0 ports – 4 (USB modem, USB Flash Drive, USB Webcam and optional Wireless USB Keyboard/mouse dongle)
100 Mbps Ethernet – 1 (optional for ADSL broadband, if available)
Interfaces – A/V in/out, Microphone in / Headphone out, IR in, VGA out (optional)

The solution supports core applications like Internet Browsing, Photo Viewer, Music Player, Video Player, SMS and Video Chat. All the applications are described in the "Applications" section. The core of the system architecture is a novel, robust and scalable framework that is flexible enough to deploy multiple classes of applications.

B. *Application Development Framework – Background Study*

There is some framework described in [11], however it focuses mainly on IPTV. It can be noted that the framework is somewhat akin to mobile operating systems like Android and iOS, which builds on top of a core operating system kernel (mostly linux / unix) and provides APIs to build applications. However all mobile operating systems are designed for small screen size and hence have a performance problem if the display resolution is increased to support large screens like TV, especially if the box CPU has low processing power. Additionally, iOS is a closed system and hence cannot be deployed on any custom hardware. Android also typically needs a higher-end processor to support its Virtual-Machine based architecture. Intel and Nokia supported Meego (www.meego.com) has been the closest match for Connected TV environment, but they never came out with a TV focused release addressing the above problems and is currently discontinued from both companies. There are also multimedia-specific solutions like Boxee (www.boxee.tv) which was initially built for converting PCs into TVs through streaming media framework and then was converted for Set top boxes. It mostly supports all the features required in the proposed system, however, it is supported only on Intel x86 architecture based CPUs like ATOM, which are costly.

Hence, it is clear that if a low-cost ARM CPU with multimedia accelerators is used, there is need to develop a complete multimedia framework to support easy development of a set of value-added information access, entertainment and

collaboration applications. The system architecture describing the framework is given in the next section.

C. Application Development Framework Architecture

The complete solution is designed using a scalable and flexible software framework on top of general purpose hardware. The software framework adheres to embedded system design guidelines and constraints and is based on basic multimedia work-flow. Fig. 2 shows the details of the framework. The framework consists of three distinct but closely knit subsystems.

1. Source subsystem (SRC) - defines from where the data has to be taken
2. Processing subsystem (PROC) - defines the kind of processing that needs to be done on the data
3. Sink subsystem (SINK) - defines where the data has to be put after it is processed

SRC, PROC and SINK consist of the following modules -
SRC – Network, Microphone, Camera, Audio in, Video in, Storage, USB
PROC – Compress / Decompress, Multiplex / Demultiplex, Render, Blend
SINK – Network, VGA, TV Video, TV Audio, Headphone, Storage

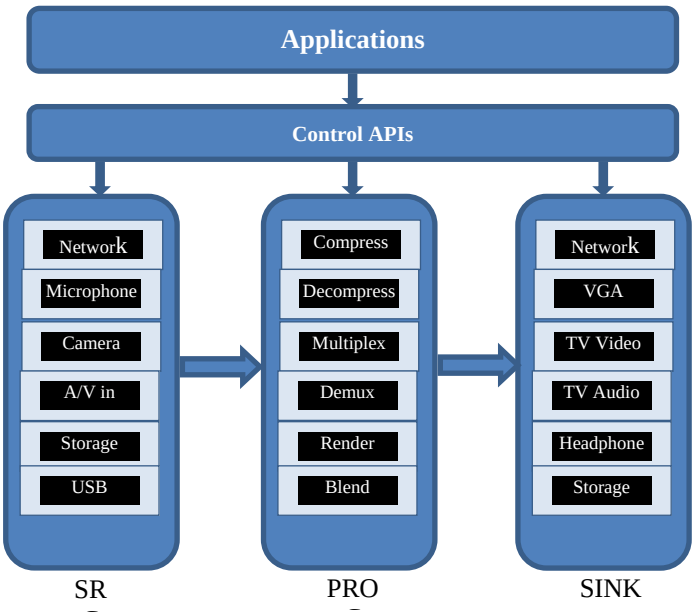

Figure 2. Framework Architecture for Different Applications

There is a set of Application Programing Interfaces (APIs) which can be used to set which modules from SRC, PROC and SINK should be used and can control the data flow between chosen modules. Table 1 shows how choosing specific modules for SRC, PROC and SINK can create different applications.

A basic description of the proposed system based on earlier work can also be found in [12].

TABLE 1. Framework Configuration for Different Applications

Application	SRC	PROC	SINK
Video from Internet	Network	Demux - Decompress	TV Video / Audio
Media player	Storage	Demux - Decompress	TV Video / Audio
Video Chat (Far View)	Network	Demux - Decompress	TV Video / Headphone
Video Chat (Near View)	Camera and Microphone	Compress - Multiplex	Network
TV Video Recording	A/V in	Compress - Multiplex	Storage
Internet Browser	Network	Render	TV Video
TV-Internet Mash-up	Network and A/V in	Render - Blend	TV Video

D. Applications

The basic applications on HIP consist of Internet Browsing, Media Player, SMS on TV Video Chat and Simultaneous viewing of TV and Internet. They are implemented on top of the framework either from open source, or from third party, or developed from scratch. Details of the applications are given below.

Browser

- HTML 4.0 with Java script and ECMA script support / CSS 1.0
- Native Java Script extension support
- File explorer
- Simultaneous TV and Browser
- Tabbed browsing
- Proxy Support
- Navigation between hyperlinks and scrolling through remote control keys
- Page-fit view to remove horizontal scrolling

Fig. 3 gives example screenshots of invoking browser from the main menu, blended TV and browser application.

Media Player

- Supported Audio Formats - MP3, AAC, FLAC, OGG-Vorbis
- Suppoorted Video Formats - MPEG1 video (VCD), MPEG4, H.263, H.264

- Supported Image Formats - JPEG, GIF, PNG, BMP
- Auto-listing of content based on media type
- Remote control based navigation

Fig. 4 gives example screenshots of Picture Viewer, Audio Player and Video Player on HIP.

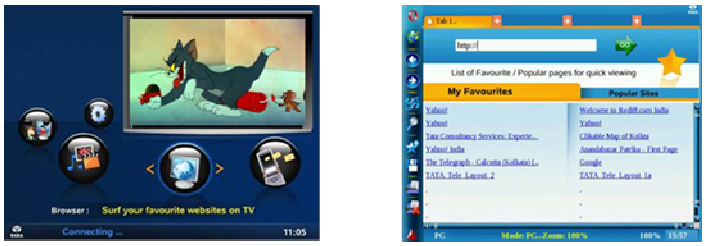

Figure 3. Main Menu and Browser on HIP

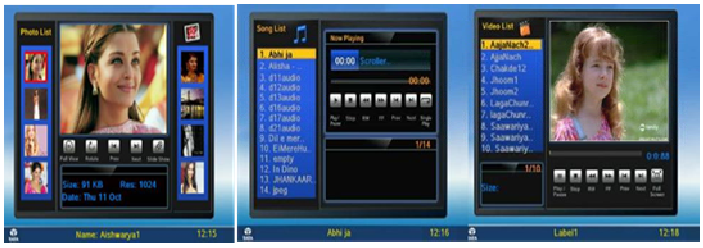

Figure 4. Media Player on HIP

Video Chat

- Peer-to-Peer connection over UDP
- Supports CIF and QCIF resolution
- Simple mobile no. based connection setup using a server-based address resolution

Fig. 5 gives example screenshots of the video chat application (session setup and live session).

Figure 5. Video Chat on HIP

SMS

- Inbox and Address Book support from SIM (both GSM and CDMA)
- Option of SMS sending while watching TV through alpha blending

Fig. 6 gives the example screenshots of the SMS application on HIP with on-screen keyboard for remote control based text entry.

Figure 6. SMS on HIP

III. User Trial

A. *Survey Configuration*

A user trial survey with HIP was conducted among the city users in India. The applications provided were Browser, Media Player (Photo, Music, and Video), SMS and Simultaneous viewing of TV and Browser through blending. The internet connection used was through a 2G CDMA1xRTT USB modem. The sample taken was 50 middle-class and lower middle-class families involving 50 working adults and 50 students (12-18 years age) [13].

B. *Qualitative Survey*

A detailed questionnaire based survey was done to gather the user feedback on their experience on using HIP. At first there were some qualitative questions on which respondents were asked to answer. The results are shown in Fig. 7. As seen from the results, slow internet connection had been the biggest concern. Adults had a liking preference order of Internet, SMS, Media Player and TV-Browser Blending while students had a liking preference order of SMS, Internet, Media Player and TV-Browser Blending. There was also significant difference between adults and students for Media Player, SMS and TV becoming interactive.

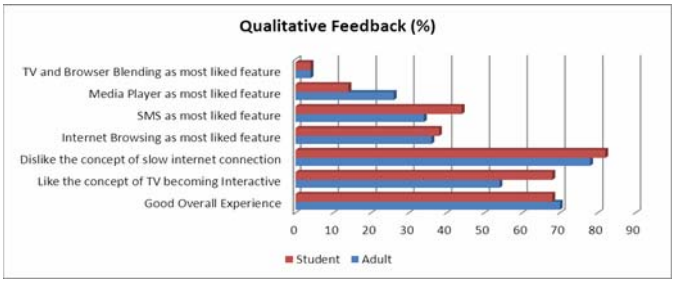

Figure 7. Qualitative Feedback

C. *Quntitative Survey*

To gain more insight into the user feedback a detailed quantitative study was also undertaken where users were asked

questions and asked to rate each application (in a scale of 5) in three different dimensions – ease of use, likeability and relevance. The results are summarized using a confidence score measure where % of respondents responding with a score of 4 or 5 is taken as relevant and are given in Fig. 8, Fig. 9 and Fig. 10 respectively. As seen from the above figures, the striking points are lack of ease of use in internet browser; low likeability and relevance of photo viewer; significant difference in opinion among adults and students for internet browser and SMS and consistent below average rating for the TV-browser blending.

Finally another quantitative study was undertaken to understand the navigation and text-entry issues. The results are summarized using the same confidence score measure where % of respondents responding 4 or 5 is taken as relevant and are given in Fig. 11. As seen from the results, adults prefer remote control as a preferred navigation device compared to keyboard (can be linked to being non-computer-savvy) and the comfort level for using the standard QWERTY on-screen keyboard layout is not good.

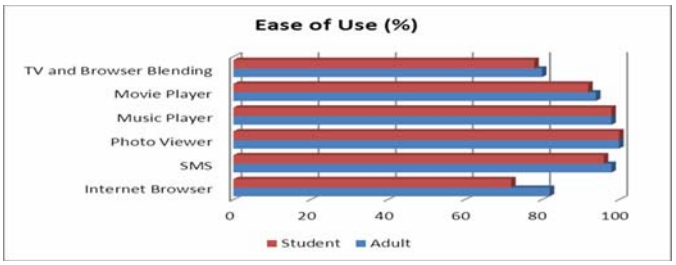

Figure 8. Quantitative Analysis – Ease of Use

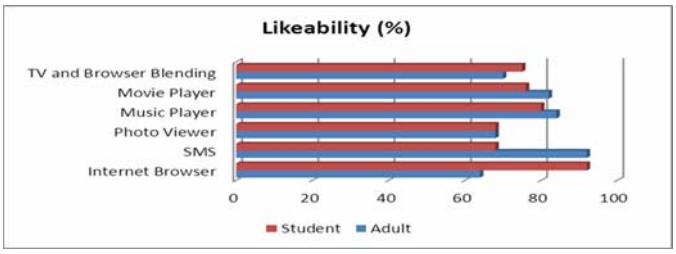

Figure 9. Quantitative Analysis – Likeability

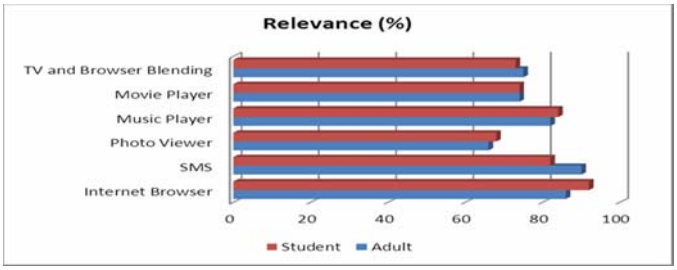

Figure 10. Quantitative Analysis – Relevance

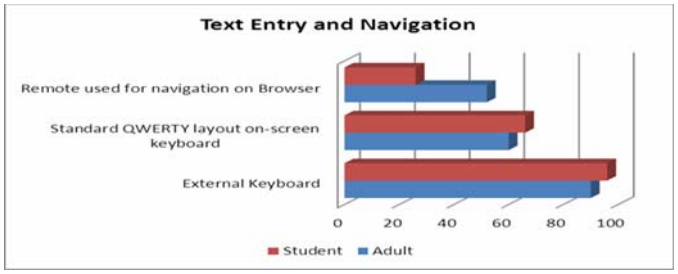

Figure 11. Quantitative Analysis – Text Entry and Navigation

IV. REQUIREMENT ANALYSIS

If we try to summarize the findings of the user study, the following interesting insights crop up –

1. Slow internet connection
2. Different levels of feedback from adults and students especially for browser and SMS, which can be attributed to generation specific preferences
3. Poor feedback on Photo Viewer
4. Lack of ease of use for Internet Browser and not much liking for TV-Internet blending
5. Preference of remote control for non-computer-savvy users and dislike of the QWERTY layout for on-screen keyboard

Based on this feedback, following action items towards improvement of the solution has been undertaken.

1. a) Providing an option for integrating with higher speed (2.5G and 3G) modems and ADSL broadband connections and providing a network condition indicator in the box that can either be used as feedback to the user to set user expectations or can be used to automatically adapt applications like video chat through adaptive rate control.
   b) Look at possibility of increasing the CPU speed while still keeping the cost low to improve the browsing experience.
2. Clearly identify the positioning of the solution in the market and target segment.
3. Improve the User Interface design of the photo viewer and its performance.
4. Conceptualizing newer ways to browse on TV where internet content is mashed up intelligently with the broadcast TV content through image processing based TV context extraction.
5. Providing a novel on-screen keyboard layout that can be easily used with remote control.

Implementation of the suggested changes has been ongoing and preliminary testing on the prototypes suggests significant

improvement of the user experience. However implementation details of these changes are kept out of scope for this paper.

V. CONCLUSION

In this paper, we have analyzed the market needs of developing countries like India and have established the need for a Television-based solution to address the digital divide problem. Based on these needs, we have presented a novel low-cost internet-enabled TV application platform called Home Infotainment Platform (HIP) as an over-the-top add-on to existing Television. We have described the hardware and software architecture of the proposed system, the rationale behind choosing such architecture and have introduced a novel flexible application development framework. Then we have described the core applications present in the box. Finally results of a user study on HIP based on a real implementation is presented and analyzed. Based on this analysis, we have tried to convert the user study results into some technical requirements for future versions of HIP.

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AUTHORS PROFILE

Arpan Pal was born in Kolkata, India in 1968. He received his B.Tech and M.Tech from Indian Institute of Technology, Kharagpur, India in Electronics and Telecommunications in 1990 and 1993 respectively.

He has more than 20 years of experience in the area of Signal Processing, Communication and Real-time Embedded Systems. Currently he is with Tata Consultancy Services (TCS), where he is heading research at Innovation Lab, Kolkata. He is also a member of Systems Research Council of TCS. His main responsibility is in conceptualizing and guiding R&D in the area of cyber-physical systems and ubiquitous computing with focus on applying the R&D outcome in the area Intelligent Infrastructure. His current research interests include Mobile phone and Camera based Sensing and Analytics, Physiological Sensing, M2M communications and Internet-of-Things based Applications. He had been earlier with Defense Research and Development Organization (DRDO) of Indian Govt. working on Missile Seeker Signal Processing. He has also worked with Macmet Interactive Technologies, leading their real-time systems group in the area of Interactive TV and Set-top boxes.

Mr. Pal has more than 35 publications till date in reputed Journals and Conferences along with a couple of Book Chapters. He has also filed for more than 35 patents and has four patents granted to him. He serves on the Technical Program Committee of several International Conferences. He is also a reviewer for Elsevier Journal for Signal Processing: Image Communications, EURASIP and Journal of Computer Technology and Applications.

Ramjee Prasad was born in Babhnaur (Gaya), India, on July 1, 1946. He is now a Dutch citizen. He received his B.Sc. (eng.) from the Bihar Institute of Technology, Sindri, India, and his M. Sc. (eng.) and Ph. D. from Birla Institute of Technology (BIT), Ranchi, India, in 1968, 1970, and 1979, respectively.

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Prof. Prasad has served as a member of the advisory and program committees of several IEEE international conferences. He has also presented keynote speeches, and delivered papers and tutorials on WPMC at various universities, technical institutions, and IEEE conferences. He was the founder and chairman of the IEEE Vehicular Technology/Communications Society Joint Chapter, Benelux Section, and is now the honorary chairman. In addition, Prof. Prasad is the founder of the IEEE Symposium on Communications and Vehicular Technology (SCVT) in the Benelux, and he was the symposium chairman of SCVT'93. Presently, he is the Chairman of IEEE Vehicular Technology/Communications/Information Theory/Aerospace and Electronics Systems/Society Joint Chapter, Denmark Section. In addition, Prof. Prasad is the coordinating editor and editor-in-chief of the Springer International Journal on Wireless Personal Communications. He was the technical program chairman of the PIMRC'94 International Symposium held in The Hague, The Netherlands, from September 19-23, 1994 and also of the Third Communication Theory Mini-Conference in Conjunction with GLOBECOM'94, held in San Francisco, California, from November 27-30, 1994. He was the conference chairman of the fiftieth IEEE Vehicular Technology Conference and the steering committee chairman of the second International Symposium WPMC, both held in Amsterdam, The Netherlands, from September 19-23, 1999. He was the general chairman of WPMC'01 which was held in Aalborg, Denmark, from September 9-12, 2001, and of the

first International Wireless Summit (IWS 2005) held also in Aalborg, Denmark on September 17-22, 2005. He was the General Chair of the First International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology (Wireless VITAE) held on May 17-20, 2009 in Aalborg. Prof. Prasad was also the founding chairman of the European Center of Excellence in Telecommunications, known as HERMES and now he is the honorary chairman. He is a fellow of IEEE, a fellow of IETE, a fellow of IET, a member of The Netherlands Electronics and Radio Society (NERG), and a member of IDA (Engineering Society in Denmark). Prof. Prasad is advisor to several multinational companies. He has received several international academic, industrial and governmental awards of which the most recent is the Ridder in the Order of Dannebrog (2010), a distinction awarded by the Queen of Denmark.

Rohit Gupta is currently the Vice President -Wireless Domain Solutions in Tata Teleservices Ltd. Earlier he was AVP & Head of VAS Business Operations and General Manger - New Product Development & Wireless Internet Services in Tata Teleservices Ltd. Prior to joining Tata Teleservices Ltd., Rohit had also worked in Reliance Infocomm and Hutch - Essar Cellphone.