Indian Railways – Backbone of Information Transport in India

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Abstract: Indian Railways is the backbone of public transport in India. With ever-increasing number of people and goods that use Indian Railways, the cost of maintenance and expansion of existing infrastructure is burgeoning. Being a medium of mass transport the railways can not afford to increase its fare to keep up with its growing expenses. There is an urgent need therefore, to look for ways to cut down its expenses, increase its efficiency, and look for additional sources of revenue, which will guarantee that Indian Railways continues to provide a similar or better service to Indian masses.

This paper explores how computer technology can be used to meet the above challenges. We specifically propose ways to computerize the Administration and Engineering offices of Indian Railways. We propose a high-level architecture of this computerization identifying the existing technologies that can be used. We analyze the benefits of this project, the work involved, and the challenges to be overcome in undertaking such an effort.

A high-speed communications network needs to be developed for interconnecting the offices of railways. This same communication network can be used to provide high-speed Internet connection to the public and lease out network capacity to Internet Service Providers. The revenue generated from these services can not only recover the expenses incurred in the process of computerization but also has a potential of exceeding the current revenue that the railways gets from fares and freight charges. The additional revenue generated can easily exceed several thousand crore of Rupees per annum.

In addition to generating high revenues for the railways, the development of this communications infrastructure can boost the Indian economy. The transportation medium used to be the backbone of any country's economy. Indian Railways undoubtedly is the backbone of public transport in India. With unprecedented growth in Information Technology, the world has now moved to an era where information transport has become the most dominant indicator of a country's economy. In this paper, we show how Indian Railways is in the unique position to become the backbone of information transport in India making India one of the best nations in terms of communications infrastructure.

Finally, we describe some caution that needs to be exercised while taking such an initiative. The development of such an expensive infrastructure should be started with a good vision of the future. One wrong decision along the way can easily render the whole effort useless or at least, lengthen the timeframe and expenses involved.

We hope this initiative of Indian Railways towards building a high-speed communication network will mark the dawn of a golden era of communications infrastructure development in India making Indian economy one of the best in the world.

1. Introduction

India is the 7th largest country in terms of its geographical size. This means there is a need for efficient means for long-distance transportation. The long-distance road network is very poorly developed in most parts of India. Bulk of long-distance traffic is carried by the Indian Railways, as a result. Indian Railways therefore, forms the backbone of public transport in India. With ever-increasing number of people and goods that use Indian Railways, the cost of maintenance and expansion of existing infrastructure is burgeoning. Being a medium of mass transport, the railways can not afford to increase its fare to keep up with its growing expenses. There is an urgent need to look for ways to cut down its expenses, increase its efficiency, and look for additional sources of revenue, which will guarantee that Indian Railways continues to serve the public without any degradation of service. In India, public transport is still a major foundation of the country's economy. So, to keep the Indian economy from collapsing it is necessary to keep the Indian Railways in good shape.

The computer technology can be used to meet the above challenges. By computerizing the Administration and Engineering offices of Indian Railways the worker productivity can be increased many fold. The same workforce will be able to operate and maintain a much larger railway network. The efficiency of the railway will increase as a result of computerization due to dramatic reduction in communication time among geographically dispersed offices. The officers of the same zone are located in geographically dispersed offices. Frequently, one task requires the consent of a hierarchy of officers. It is not uncommon for one file to traverse 2 or more offices before it is finally approved and more traversals through another couple of offices before actual work can start on its basis. The same file that now takes weeks to reach from one office to another will take few seconds. Another example could be locating a file to work on. Sometimes, it easily takes half a day to locate a file from the pile of files stored in racks. With computerization, it can be done in milliseconds. Yet another example is preparing applications and reports. It takes many hands to prepare a report (a typist, a clerk and at least one officer and not to say many revisions). With computerization, a single officer can do this job in less time than it takes him/her to revise the typed document multiple times. More often, templates are available which need a couple of changes to prepare a specific application (a matter of few minutes). There are numerous examples and we will list some of them in detail in Section 3.

In this paper, we specifically propose ways to computerize the Administration and Engineering offices of Indian Railways. We propose a high-level architecture of this computerization identifying the existing technologies that can be used. We analyze the benefits of this project, the work involved and the challenges to be overcome in undertaking such an effort. In order to allow communication among computers located in geographically dispersed offices, a communications network needs to be developed. This same communications infrastructure can be used to provide high-speed Internet connection to the public and lease out network capacity to Internet Service Providers. In order to store the files and reports and allow authenticated and easy access to them from any location, Storage Area Networks (SANs) needs to be developed. These same SANs can be used to sell storage services to other government organizations, private organizations, and web-hosting companies. The revenue generated from these services can not only recover the expenses incurred in the process of computerization but also has

a potential of exceeding the current revenue that the railways gets from fares and freight charges. As we show in Section 5, this can easily exceed several thousand crore of Rupees per annum.

In addition to generating high revenues for the railways, the development of this communications infrastructure can boost the Indian economy. The transportation medium used to be the backbone of any country's economy. Indian Railways undoubtedly is the backbone of public transport in India. With unprecedented growth in Information Technology, the world has now moved to an era where information transport has become the most dominant indicator of a country's economy. In this paper, we show how Indian Railways is in the unique position to become the backbone of information transport in India making India one of the best nations in terms of communications infrastructure.

Finally, we describe the cautions that need to be exercised while taking such an initiative. The development of this highly-technical and expensive infrastructure should be started with a good vision into the future. The fiber cables deployed should be able to support capacities of the order of Terabits per second. The network should be designed in such a way as to allow future expansion. Best communications experts in the world should be inducted to the advisory committee to make these possible. Further, the communication equipment deployed should be modularly expandable so that the initial deployment cost is lower and at the same time these can be upgraded in future to handle higher loads as the traffic increases.

One wrong decision along the way can easily render the whole effort useless or the least lengthen the timeframe and expenses involved. In this paper, we identify the appropriate technologies that should be used at every stage, providing an insightful reason behind every such choice. All along we have tried to identify the most modern technology available that will offer the best performance, can be deployed in the least time, and that will require least infrastructure. We believe this paper will lay a solid foundation for development of a high-speed communication network in India, which in turn will mark the beginning of a golden era of Indian economy based largely on network-based Information Technology.

2. Growing Economic Burden

Long-distance road transport network is either non-existent, underdeveloped, or poorly maintained in most parts of India. The burden of carrying long-distance traffic, whether public or goods, therefore falls mostly on Indian Railways, which is doing a great job with it. However, as we will see in the following, this great organization will soon be in trouble if it continues to operate in the same way as it is operating now.

The population of India is growing and so is the load on the railways. To better serve the growing population, at least one new train is introduced every month. To allow the growing number of trains to move without much interference with each other, tracks need to be well-maintained and need to be continuously expanded. New stations and new platforms in existing stations are being built every day. All this costs money. The cost of operations increases with growing infrastructure. Further, growing infrastructure requires higher maintenance, which again is a cause of growing expenditure. In total, to maintain the same quality of service, the Indian Railways has to keep spending more money everyday.

The revenue for the railways does not increase at the same rate and can not increase at the rate with which its expenditures are increasing. Primary sources of revenue for the railways are fares from passengers and freight charges from goods transportation. Indian Railways is the primary means of transportation for both short-distance and long-distance travel for majority of Indians. If the fares are increased to keep up with growing expenses, many people will not be able to afford traveling by railways(of course, many will continue to travel without paying fares. But that is beside the point. Law enforcement can decrease the number of such passengers, but can not eliminate it entirely). India is a socialist and a developing country hosting 2nd largest number of people on earth. And so, fare hikes are controlled because it can affect millions of Indians. But as far as Indian Railways is concerned as an organization, its income is not growing to keep up with growing expenses.

Therefore, the railways has to look for ways to increase its efficiency, cut down its expenses, and look for additional sources of revenue in order to keep providing a similar or a better level of service to the Indians. In this paper, we propose computerization of Indian Railways' offices, which can help meet all the three objectives outlined above.

3. The Benefits of Computerization

Today, Indian Railways is one of the most efficient government-controlled organizations in India. It houses one of the most brilliant engineers and administrators in the country. This is the reason it has continued to remain at the center-stage at the India's economic development. Until recently (before Information Technology revolution), any country's economy heavily depended on how effective the transportation medium of that country was. And, Indian Railways have continued to serve the Indian masses well, despite increasing burden. However, as we will see in this section, looking from the perspective of current state of the technology available in the world, current modes of operations in Indian Railways can be vastly improved with computerization.

The benefits of computerization are manifold. Below we list few of them:

- The time to search for any file irrespective of whenever it was stored, whoever created it, and whatever section/office it is stored in, it can be accessed by proper authorities in seconds.
- Time to prepare a document or a report will be highly shortened. Templates for all kinds of applications and reports can be stored in a central server. To create a new application the concerned authority only needs to make a couple of changes to the templates available. No need to involve a typist, a clerk and an officer. It can be easily done by an officer alone.
- The status of various engineering and construction works in progress can be made available online. Any higher authority can track the progress of a work only by looking at this status online from any office.
- Issuing a tender for any engineering work takes a couple of months. With computerized offices it can be done in days. The work order can be issued within days after a decision has been reached whether to get any work done. The time to completion of any work will reduce by at least a couple of months.
- The billing process can be improved as well. The time to approve a bill can be reduced to seconds. Once a work status has been prepared by the officer on site (which anyway will be available online), the higher authorities can sign it

digitally within seconds, and the verification from the accounts can also be performed automatically within seconds without the involvement of any more persons. Many times work in progress is hampered because payment for previous work has not been made. If the billing process is automated this waiting period will vanish. As a result, the engineering works of railways will mostly finish on time or even before time.

- Budgeting process can be automated. Some accounting software available today can be employed for this purpose. No need to perform huge calculations and coordinate with different offices. All information about the needs of different divisions and all the available money for a year will be stored on computers and accessible to the appropriate authorities. This process which takes a lot of effort, a lot of manpower and lot of time can be done by only few officers.
- Performing inventory management manually not only takes great time, effort and manpower but also causes wastage of time and resources. Sometimes, work in one division may be stuck due to lack of availability of a material that may be lying idle in the stores in another division. With the use of supply chain management software and automating the inventory management process not only can the time and effort involved in inventory management be reduced drastically, but the usage and distribution of resources will be highly optimized leading to savings in expenditure.
- Connecting the computers in various offices has many other benefits too. Employees of railways are frequently on move. If the computers in various offices are connected, the employees can continue their work even when they are away from their offices.
- A lot of travel can be avoided if computers in various offices are connected with a high speed communication network. Videoconferencing can be used to hold joint meetings between officers who are posted in geographically distant offices. This improves productivity of employees. Its not unusual to spend a day or two in traveling to attend meetings.
- Works in progress can be monitored through online video. This can cut down travels, which can increase the productivity of the officers. It's a known fact that officers in railway are more busy with travel than actual work. If they are allowed to work from their office their productivity will increase dramatically.
- Finally, Indian Railways can easily earn several thousand crore of Rupees per annum once they develop a high-speed communications network as we suggest in section 4.4.

4. A High-Level Architecture of Computerization

In this section, we propose a high-level architecture of the computerization of offices of Indian Railways. We specifically list the resources needed, ways to organize them and ways to operate them. To perform any task there are numerous technologies available today. We recommend one or a few potential candidates for each such choice. We also provide our insight behind each technology we recommend.

4.1 Choice of Computers and Software

The basic need in a computerized office is a computer for every employee who needs to work with documents. There are several brands of Personal Computers (PCs) available in the market. However, there are several drawbacks to using PCs in an office environment like that of Indian Railways:

- They are a costly proposition especially for such a large organization like Indian Railways.
- PCs are prone to security attacks because new software (potentially malicious, e.g. virus-infected) can be readily installed on any PC through the floppy drives or CD drives. This can easily spread into the network if all the computers are interconnected.
- Each employee who manages his/her PC has to be well-versed in managing the PC in order to prevent its malicious use by others. Otherwise, the data maintained will no longer be secure. Moreover, if one PC is compromised, it has a chance of affecting other computers too.
- Typically, one person will be configured to work on his/her PC. In an office like Indian Railways, where employees are frequently transferred from one office to others and where officers are frequently on move to attend meetings, inspections, emergency duties, etc., it will be difficult to have full access to their machines while away.
- The necessary files which typically are shared among many employees (clerk, Inspector of Works, Area Engineers, Divisional Engineers, Divisional Railway Managers, etc.) constantly has to be sent from one machine to another and then to the third, and so on. Sometimes the files kept on different machines may be inconsistent (older versions of the same document may be spread across different machines), which will lead to misunderstandings.

In view of these problems, we suggest another alternative. We propose that all employees be provided with thin-client computers (terminals) which do not have any kind of storage like floppy drives, hard disk, CD-ROM drive, DVD drive, etc. Few protected machines can be kept in every office where the CDs, floppy disks can be used. These machines can be well managed by trained people so that no virus-infected software can make it way into the railways' network (We explain later what we mean by railways' network).

There should be few servers which will maintain the login accounts of all employees. The login servers of different offices will be connected together so that when an employee moves to another office (temporarily for a day or permanently), the account profile of that person will be available to him/her wherever they log into the railways' network. The employees will not be bound to any particular machine. They can use any free terminal from anywhere Indian Railways has its office and it will look like their own machine. For example, if someone was working on a document at one machine in Patna when he had to travel to Calcutta on an official trip the very next day, he can continue working on the unfinished document in Calcutta as if the machine in Calcutta was his own machine. That is the beauty of networked computers.

There are many options when buying a thin client and login servers. Network Computing Devices' thin-client is one such option. Login servers can be bought from Sun Microsystems, Dell, HP/Compaq, etc.

A couple of servers should be used in every office depending on the number of thin-clients installed. There are multiple benefits to having many moderately-powered servers than having a single server: the number of servers can be increased as the size of office grows and if one fails or needs to be upgraded, work of users working on a down server can be transferred to other up servers and they can continue to work without noticing any glitch in their work. All the servers in one office can work together cooperatively using clustering technologies.

The login servers in different offices of Indian Railways should be interconnected to each other and the profile of one user should be transmitted to other servers as the need arises. One such situation may arise when all server in one office needs to be restarted or needs an upgrade. The users who were logged into those servers can be transferred to other up servers. Another such situation may arise when some user moves to a different location and wants to work from there. The profile of the user in consideration should be transmitted from the login server at his home office to the login server at the desired location.

In terms of software, we suggest the following:

- The operating system of choice should be Windows XP because it is very easy to use. Many employees are already conversant in using Windows on their home PCs. Others who have not used it yet will require very little training to use it.
- The software to computerize the operation of the railway offices needs to be developed. However, it will not be as costly and time-taking as it used to be for computerizing other offices in the past. The reasons are that software developing companies and software developers have learned from developing software for computerizing other offices and the necessary experience is there. Further, general purpose software are available for accounting and document storage which can be customized for Indian Railways. Having said all that, it still requires some significant investment and time.
- Email and Internet access should be provided at every terminal so that the employees can communicate via email with each other and can have access to the latest information available in the world. Its also possible to provide Internet access at only few selected computers in every office. But, email service should be provided at every terminal. It will reduce the communication time between employees from weeks and months to seconds. Imagine the effect on the productivity of the employees!

4.2 Choice of Storage Technology

As suggested in Section 5.1, the employees should work on servers using thin-clients to access their profile and the documents. The documents which are to be shared between multiple users should be stored in a Storage Area Network (SAN), which makes them available to everyone. Of course, only those users who have appropriate access rights for a particular file will be able to access it. For example, a Divisional Railway Manager (DRM) can be granted access to all official files of his/her division, a DEN (Divisional Engineer) can be granted access only to those files pertaining to his/her area of control, and so on.

Once a file is prepared by an employee, the higher level authority can be notified of its availability, who can then review it, sign it (digital signatures can be used), and notify

the officer next up in the hierarchy. Notice how this mechanism is independent of the physical location of people. The Inspector of Works (IoW) can be sitting in Mor, the Area Engineer (AEN) can be sitting in Mokama, the DEN can be sitting in Danapur, the next higher up authority may be on travel (say in Hazipur) and all of them can sign the same document within a matter of minutes. Notice that if this document needs verification from accounts people, it can be done quickly too because the account verification process can be automated and the accountant can perform the check in seconds (No need to search through a bunch of files in the racks).

A Storage Area Network (SAN) is a small network of high storage servers whose only job is to maintain files, enforce the access according to access rights of the users, provide recovery against failures of any one server (no loss of valuable data in case of failures), and most importantly provide access from remote locations. The user can be located in Jammu and the Storage Servers may be in Kanyakumari and still the time to access the files will be of the order of seconds (under the assumption that the transport network is implemented as we suggest in section 5.4).

We also propose that one SAN be built to serve multiple offices. Typically, one SAN can serve a hundred office, at least. The SAN can be located independently from the regular offices. The administration of the SAN should be well-managed for they are the ones who store all the valuable and sensitive data. If there are a few of them, they can be managed and protected well enough.

4.3 Choice of LAN technology

As we suggested in sections 5.1 and 5.2, the files are located at servers. No files are stored at users computers. We also suggested that the users should not be tied to one machine. They should be able to work and access any file they are permitted to, from any location. Clearly, there is a need to connect the user's thin clients to the login servers and the SAN servers. In this section, we suggest technologies that should be used to connect the thin-clients and servers in one office. This network, which spans across few kilometers at most, is also referred to as a Local Area Network (LAN).

Several options for LANs are available including 100 Megabits per second and 1 Gigabits per second Ethernet, ATM, and infrastructure-based wireless LANs. We pick infrastructure-based wireless LANs with Gigabit Ethernet used to interconnect the wireless LAN ports. The reasons for our choice are the following:

- Wireless LANs are easy to install. Very little wiring is necessary.
- Wireless LANs are easy to maintain. The computers can be moved around and no worries about wires breaking and disrupting services. After all, there are very few wires to be broken. The few wires needed can be well maintained and well protected.
- Since fewer wires are needed, the installation time is reduced.
- Installing fewer wires also means savings in expenditure on infrastructure.
- In addition to the thin-client terminals, users may use their laptops to connect to the network and employees with laptops can work from any place in the office complex. They do not have to be seated inside their office on a terminal.
- IEEE 802.11a based wireless LANs provide a bandwidth of 54 Megabits per second which is sufficient for upto 50 users. If there are more, more wireless ports can be installed.

- If IEEE 802.11b based infrastructure is used which provides a bandwidth of 11 Megabits per second, more ports will be needed to support the same number of users. The choice should depend on the size of the office.
- The wireless ports in an office should be connected using Gigabit Ethernet. Gigabit Ethernet has been standardized and provides sufficient bandwidth for one office even if there are multiple videoconferencing sessions going on in the same office. 10 Gigabit Ethernet is not yet standardized and is too costly. Moreover, 10 Gigabit per second is too much bandwidth inside an office.

However, there is one concern with wireless LANs. The security of these LANs needs to be well managed to prevent unauthorized access to the facilities.

4.4 Choice of Network Equipment

Once the computers (thin clients and servers) are connected to each other in the same office, users in one office can use any thin client located in that office to access their profile. But, our vision is to provide access to all the files by all authorized users all the time and from any place. This requires interconnecting different offices. In this section, we provide an outline of a transport network that needs to be built to achieve this objective.

There are many options for interconnecting different offices. The simplest is to lease network bandwidth from Internet service providers like P&T, Satyam, etc. However, the problem here is, the communications infrastructure of these service providers in India is not highly developed to fulfill the bandwidth needs of railways. Moreover, their network reach is very limited and so very few offices (only those located in larger cities) can be interconnected. A third discouraging factor is that Indian Railways will always be dependent on the quality of service that these companies provide and they will have to keep paying leasing charges to these companies. We suggest a better alternative, which not only can fulfill all the bandwidth needs of the railways and connect all the railway offices, it also has a potential for becoming another source of revenue for the railways that can potentially exceed the revenue railways gets from fares and freights.

Our suggestion is based on an observation that Indian Railways owns railway tracks in India and together with the tracks it owns few meters of ground on both sides of the track. These few meters of ground are the *gold* of today's world. This ground is referred to as *Right Of Way* in the telecommunications world. These few meters of ground on both sides of the track have a potential to bring at least few thousand crore of Rupees annually to the Indian Railways in the form of lease charges and Internet service charges. The railway network in India is the largest in the world. The tracks of railways have an extensive reach in remote areas of the country, where the service provider companies may take decades to reach. Another observation is that most of the offices of Indian Railways are located within few kilometers from the tracks. These observations led us to suggest the following:

- The Indian Railways should build a communications network of its own. The first task is to lay fibers on both sides of track (located as far from tacks as the railway owned ground extends – the reasons are explained in Section 7). The costliest part in laying fibers is not the cost of the fiber itself but it is the labor cost. The Indian Railways has an advantage here because it has a huge labor force (permanent and temporary) who keep doing some maintenance job on tracks. The same labor

force can be used to dig trenches and lay cables. Some caution needs to be exercised here, which are described in Section 7.

- Once the fibers are laid, some of the capacity of these fibers can be leased immediately to Internet Service Provider (ISP) companies and cell phone companies in order to recover the cost of laying fibers.
- Central Offices need to be built near the tracks which are also called Points of Presence (PoP). These small buildings will hold switching equipment.
- Once the buildings are ready, switching equipment and routers need to be bought. The switching equipment (telecommunications switches) should be such that they cost less in the beginning and can be upgraded as the bandwidth requirement increases. The first network equipment is an Ethernet hub. Ethernet hubs are needed in large offices to connect the wireless LAN ports. These are very cheap.
- Routers need to be bought to interconnect various offices. At least one router will be needed per office. Routers come in all varieties and prices depending on the bandwidth desired. Routers can be used to interconnect the LANs in various offices and it will appear to the Ethernet hubs that they are logically connected to many other Ethernet hubs simultaneously. That is the beauty of using routers. The routers are very cheap today and are dropping in prices every day. Cheap and smaller routers may be bought from Cisco. High-performance routers which will be required in larger cities and can be bought from Juniper.
- The routers in various offices need to be interconnected to each other. If we use one fiber to connect a pair of routers, we will need n*(n-1)/2 wires to interconnect n routers. Even for a small number of routers, say 40, we will need 40*39/2 = 780 fibers. Typically, we will have hundreds of routers, if not thousands in railways' network. Imagine the number of fibers needed. This is why we need switches. Ethernet switches are a very cost effective solution to aggregate data from many routers and to interconnect them. Ethernet switches can handle upto 10 Gigabits per second of data on each port. One Ethernet switch may have several ports. Therefore, the next equipment to be deployed should be Ethernet switches. Some companies to consider for buying Ethernet switches are Riverstone and Foundary.
- In order to interconnect many Ethernet switches, we need higher capacity telecommunication switches. These switches should be optical switches with both electronic and optical switch fabrics. These switches can handle upto many Terabytes of aggregate data. We suggest using optical switches because they offer a very high switching capacity. They are easier to maintain. Moreover, they can be upgraded on a need basis. Some companies to consider for buying optical switches are Ciena, Corvis, Nortel, Lucent, Tellium. Ethernet Switches should be used as much as possible. These switches are very cheap compared to telecommunication switches. In fact, it is possible to build the whole communication network of railways using Ethernet switches and routers and use just a couple of telecom switches at locations which exchange high traffic like in metropolitan cities.
- The Indian Railways will need to lease some Internet capacity from VSNL or buy it directly from other renowned network carriers in the world (like AT&T, Sprint, Quest, etc.). This is needed to connect to the outside world in order to provide Internet access. Its also possible to form some partnership so that railways needs

to pay very little or not at all. Some agreement can be forged with reputed foreign service provider companies where railway can allow them use of railway's network in India and in return for them carrying railway's traffic heading for outside world.

- Railways will also need to recruit highly-talented and well-qualified individuals to build such a network and to maintain it. Maintenance of such networks are very essential in order to guarantee its continued operation. Equipments do fail and will fail. Fibers do get cut and will get cut. Its necessary to prevent disruption in service failures even in the presence of such failures. Two things are needed to achieve it. First, the network should be designed to be robust, which can withstand failures. Second, highly-qualified individuals should be recruited to maintain such a network.
- Additional details of the architecture can be obtained from the authors.

This is only a high-level architecture of the network that railways needs to build. This architecture is not very different from what a modern network looks like from within. The only difference is that we have suggested an architecture for the most modern network in the world. We have also kept in mind that the technologies we suggest should cost least and be future-proof. If implemented in the manner we have suggested the Indian Railways will have the most cost-effective and modern network in the world. The existing network carriers like P&T or Satyam can not afford to build these networks because they already have some infrastructure existing in their networks and are constrained to deploy only those equipment which can interoperate with its existing ones.

4.5 Some Additional Services

There are some additional services which can be offered to railway employees once the communication network is in place. We suggest in this section that the same communication infrastructure can be used to provide telephone service to all railway employees. It no longer has to maintain a separate telephone network of its own. Each office can have fax machines attached to some of the computers and the same network that railways will develop to interconnect various offices, can be used to send and receive fax. Further, the same infrastructure can be used to offer videoconferencing across different offices.

Providing telephone service is easy. A VoIP based PBX can be bought from a company like CISCO and the existing telephones can be connected to this PBX, which can talk to the telephone exchange of railways using the railways' network. Additionally, a microphone and speaker can be attached to every terminal and the need for a separate handset for telephone disappears.

Providing FAX service is even easier. A fax machine can be connected to a computer that is connected to the railway network and using existing technology, it can fax a document to any other computer connected to the railway network. If the fax needs to be sent/received from a fax machine connected to P&T, some mechanisms need to be deployed in the VoIP based PBX. Most VoIP based PBXs already have this capability.

Videoconferencing across different offices is even easier. A videoconferencing software can be installed on some computers in every office and the videoconferencing equipment like camera, speakers, microphones and projectors need to be deployed in a conference room to make this happen.

The above arguments may seem futuristic. The point being made here is: if the railways has a new communication network with high bandwidth, built as we have suggested, it can easily support computer communication, telephony, fax, and videoconferencing. The technologies to make them happen exist today. Its only the network needed to support them that is not available. If the railways builds a network that can support it, it can get all the benefits.

5. An Alternative Source of Revenue

Once the offices of the Indian Railways is computerized, it will not only boost its efficiency, cut down costs to justify the expenses incurred in building such a huge communications infrastructure, but also has a potential for generating revenue for the railways, potentially more than it gets from fares and freights. In this section, we describe the services that can be offered by the railways' network:

- **Leasing Network Capacity to Internet Service Providers –** Once the fibers have been deployed, and switches have been installed, network capacity can be leased to Internet Service Providers. The backbone of the railway network can potentially run at several Terabits per second (a Terabit per second is equivalent to 1,000,000 Megabits per second). Few megabits per second of bandwidth can be leased for several lakhs of Rupees per annum today. Imagine how much of revenue can be generated by leasing out just 1% of network bandwidth. A simple calculation shows that a hundred crore Rupees can be generated by charging jus one lakh Rupees for several megabits per second per year. This is only between two cities. Similar capacities can be leased out between other pairs of cities. The revenue can easily touch a thousand crore Rupees per annum and potentially exceed a 10,000 crore Rupees per annum. Not many service provider companies are there in India today but, there will be a sharp increase in the number of such companies and the amount of network bandwidth they need once there is high-speed Internet access available. The elasticity of this market is 2.5. Think of the elasticity this way: Today the Internet access is painfully slow in most parts of India. Still, so many cybercafes have sprung up. And, all of them are earning money. These cybercafes typically have one or two telephone connections, which offers at most 56 kilobits per second of peak bandwidth. Several users share this capacity. If a high-speed Internet access is available to people at an affordable price, imagine the increase in the bandwidth and in the number of Internet Service Provider Companies springing up to reap the benefits. The growth in bandwidth will only be exponential. This is one reason why Reliance is working so hard at laying fibers.
- **Providing Internet Access to Public living near the tracks -** A good amount of population resides within few kilometers of railway tracks. There are many wireless local loop technologies existing and several others in development by start up companies. These technologies require one equipment to be located near the track connected to some Central Office (where switches and routers are located) through wires. The people who subscribe to the Internet service from railways network need to buy a small card like an Ethernet card and need no wiring. Once they have a card and the railways provides them with an account, they can start using the Internet through the railways network. Very little

investment is needed by the railways in order to provide such an Internet access service. It can easily be provided in railway colonies which are always within few kilometers of the track and near to railways' offices. Of course, wired services (like cable modems, DSL, Ethernet based Passive Optical Network, etc) can be used to provide Internet access to people staying further away from railway tracks. But this will require some investment from the railways to build the necessary wiring infrastructure and maintain. One option is to team up with local cable companies and use their cable wires to provide Internet access. The point is: the railways, without spending much, can easily provide high-speed Internet access to common public and businesses located near the railways tracks (and by teaming up with local cable companies to locations further from the tracks). The amount of revenue generated from such services can easily exceed a 100 crore Rupees per annum. (The calculation is 200,000 people paying 400 Rupees per month). This is a very low estimate. The actual revenue can only be higher. Businesses can easily pay several thousand Rupees per month which have not been counted in the above calculation.

- **Leasing Storage Capacity –** We suggested to deploy a Storage Area Network (SAN) where all the shared documents can be stored. These documents can be accessed from anywhere in the railways' network. Increasingly, most of the web hosting companies and other organizations will use these storage services to store their data. The SAN built for Indian Railways can be used to lease storage space to the web-hosting companies, private organizations and other government organizations. This will generate additional revenue easily exceeding several crores of Rupees per annum. This will at least recover the expenses involved in building and maintaining these SANs.

We have illustrated only the most notable services that the railways network can offer to people resulting in a significant additional revenue. It is not hard to come up with many more services which will generate more revenue. The railways is in a unique position to capitalize on this great opportunity. The sooner it acts, the better it is.

6. A Savior of Indian Economy

In this section, we argue how building a high speed network by the railways can not only lead to an economic boom in India but is necessary too, if Indian economy is to keep growing at its current rate or at a higher rate. Until recently, mode of physical transportation used to be a deciding factor in the economic development of a country. In India, this burden was mostly borne by the Indian Railways, which has continued to contribute to the Indian economy by providing a satisfactory service to Indians.

After the Information Technology revolution, the communications infrastructure which carries information from one place to another has become a more dominant indicator of a country's economic status. Developed countries like USA, Japan, UK, France, Germany, Korea, etc have a good communication infrastructure which puts them at an advantageous position with respect to the rest of the world. China has already started laying fibers and developing a high speed communication infrastructure. Many developing countries like Brazil are following the suit. India is yet to make a head start.

The onus of developing communications infrastructure for information transport lied mainly on the P&T, VSNL, and some early start private companies like Satyam, Wipro,

and recently Reliance. None have produced a satisfactory performance to keep up with the rest of the world. P&T and VSNL are reeling under pressure to maintain their current network, which being based on primitive technologies, requires a high maintenance. Newer companies do not have sufficient resources in terms of land ownership and capital needed to build a good communications infrastructure. The situation is not too bright for India.

India made a great impact on the world in nineties by providing its brilliant IT workforce to the best companies in the world. The new millennium needs a different mindset and a different infrastructure. Any country that wants to rise in today's world needs a high-speed communication infrastructure. A high-speed communication infrastructure attracts businesses because they can interconnect their offices located in different cities and in different countries, to work cooperatively. A high-speed communication infrastructure fosters innovation because people can work with new technologies, share ideas, and try new technologies on the network. In future, we will witness that almost all cool technologies and applications will either be developed on the World Wide Web (WWW) or at least will involve the use of web. Any country with a poor communications infrastructure will be left behind. India currently is in this transition phase and not well-positioned to capitalize on this opportunity. However, the situation is not all too gloomy. There is a ray of hope. This is where the railways network comes to the rescue.

The Indian Railways has the necessary land needed to lay fibers. Indian Railways has a huge workforce which can be utilized to build this new communications infrastructure without much additional labor cost. Indian Railways has many brilliant employees who are highly qualified and many of them can be diverted to this new networking division to maintain the railways' network. Computerization of the offices will enhance the efficiency of employees. Railways will need much less number of engineers per division than it has today. Rest can be transferred, after due training, to take care of the railways' network. The initial investment to build the network can also be borne by a self-sufficient organization like the Indian Railways.

The railways has all the right resources necessary to build a high-speed communication network in India. And as we argued, it is in fact necessary for the railways to take the initiative and build this network if India is to stay ahead in the IT technology race in the world. No other private company or government organization is in a right position to build this network. Therefore, by building this network, not only can Indian Railways improve its efficiency, cut down its expenses, and generate significant additional revenues but also can become the backbone of information transport in India, a necessary catalyst to boost the Indian economy.

7. A Cautious and Calculated Start

Building such a huge and highly technical infrastructure such as a communications network in India needs to have a very thoughtful and calculated start. Many things can go wrong if the start is not cautious and an informed one. Here is a list of things that can go wrong and cautions to be exercised to avoid them:

- Deploying older equipment can render the railways network primitive as is the state of P&T or VSNL network in India. The vision of a high-speed network will not be successful as the older equipment can interoperate with only a given type

of equipments. Further, these older equipment require huge maintenance, rendering the railway network either inoperative or highly expensive. So, the equipment deployed should be a modern piece of equipment which has standards-based interfaces.

- Deploying high capacity switches at the initial buildup time can be a very costly proposition and initially there may not be enough traffic to justify this high expenditure. Therefore, the switches or routers bought should be modularly extensible. They should not only have high number of slots for inserting line cards as the number of devices connected to it increases but the switching fabric (also referred to as "backplane") itself should be modularly extensible. This will result in lower expenses at the beginning and as the railways starts getting revenue and as traffic starts growing, already deployed equipment can be upgraded in place at a relatively manageable incremental price.
- Deploying costly equipment in a wrong configuration can result in stranded investment. The telecommunications switches and high-speed routers are very expensive. A correct, robust, and extensible network architecture is very necessary to come up with before the actual deployment of devices can begin.
- The fibers should be laid as far as possible from the tracks. If they are too close to the tracks, the vibration caused due to the running of trains on the tracks can cause data loss in the fibers.
- One train derailment every year is not unusual. In case of train derailment the fiber cables can be broken. Therefore, it is necessary to lay fibers on both sides of the track. This is what we call in telecommunications world, a *diverse path*. It is very necessary to build a robust network, which continues to work even if there is a fiber cut or a breakage due to train derailments or some other inadvertent accidents.
- The fibers laid should be of very high quality that can support high data rate. It is not unusual to have hundreds of fiber strands in one fiber cable and several fiber cables bundled in a sheath. Each fiber strand should be capable of carrying at least 40 Gigabits per second on each of the hundreds of wavelengths that it can support. Effectively, one fiber strand should be able to carry more than 4 Terabytes of data. These kinds of sheaths should be deployed so that fibers by themselves can be leased to other companies. It is a very profitable business to lay the fibers and lease them out. Today, the Internet traffic is not much in India. But it will grow exponentially if a high-speed access is available to Indian people and businesses at an affordable rate.
- Many of the most notable network experts in the networking technology in the world are Indian by origin. A committee should be formed of such world-renowned experts before the actual work of building a network can begin. This will ensure that the railways network has a futuristic and right start.

8. Conclusion

We proposed computerization of Indian Railways as a means to increase the efficiency, cut down expenditure and generate significant additional revenue, of the order of several thousand crore Rupees per annum. The same workforce that Indian Railways has today will be able to handle a much larger workload in a computerized environment.

We also proposed building a communications network for interconnecting the computerized offices of Indian Railways. This network can serve as the backbone of information transport in India. This railways network can be used to provide high-speed Internet access to Indian public and businesses. The Storage Area Network (SAN) built by the railways can be used to lease storage capacity to web-hosting companies and other companies and government organizations. We also argued that Indian Railways is in the unique position to build this high-speed communications network. Further, we also argued that it is vital for the Indian economy that the railways takes the initiative to build this high-speed communication network, if Indian economy is to compete with the rest of the world. The communications network, if built by the Indian Railways as we have suggested in this paper, may witness the rebirth of Indian Railways as the dominant communications service provider in India and rebirth of India as a highly developed economy with the best communications infrastructure in the world.

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