A Survey of Data Network Options for Rural Areas: A Business Model for Asynchronous Messaging

Abstract

To make a rural connectivity project sustainable requires rigorous planning. We created models for estimating cost and revenue based on technology options and usage patterns. A comprehensive survey of various network technologies culminates in a cost calculator, which can be used to approximate an implementation budget. Anticipating bandwidth and energy constraints, we recommend communicating asynchronously at high latency to conserve scarce resources and minimize cost. To support revenue generation, a cooperative franchise utilizes peer groups to train and motivate entrepreneurs as they develop and market ICT services that address consumer demand. This multilevel, for-profit business model takes into account the critical role that adoption rate plays in determining profitability. Finally, an actual case study demonstrates how to apply this framework to make informed technological and business decisions and thereby move a project closer to sustainability.

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I. Introduction

Characteristics of rural areas

Rural areas in developing countries present especially difficult challenges to the development of networks and sustainable business projects. These challenges include unreliable electricity, limited or non-existent telecom infrastructures, poor road infrastructures, diverse topology, and low village density. These challenges are coupled with limited skill sets and limited financial resources among members of the communities. Members of rural communities are often characterized with high illiteracy, limited business skills, little technology skills, and lack of access to capital.

Asynchronous delivery methods

We pursued a model of asynchronous delivery methods to tackle some of the technical challenges in rural areas. Asynchronous delivery methods have different characteristics at the hardware and application level. At the hardware (or network) level, an asynchronous model could entail periodically turning on and off the whole network. At the application level, an asynchronous model, as we envision it, entails connecting to the Internet on need basis (staying offline until a request for Internet data), caching content in hard drives, and delaying transfer of data to off-peak hours. At both levels, an asynchronous model is not constrained by delay, since connections to the network are scheduled and moderated.

There are many benefits to asynchronous delivery methods. At the hardware level, an asynchronous model would require less power since less energy is spent having the radio on. An asynchronous model at the hardware level could also decrease maintenance costs, since down time only increases delay and does not disable service. At the application level, an asynchronous model using our proposed characteristics could lower the bandwidth requirement, decrease network technology costs, and limit over utilization (more users can use the system since full-time access does not need to be guaranteed). The focus of our research is an asynchronous model at the application level. For a discussion of asynchronous delivery methods at the user level, see Appendix A.

Research Questions

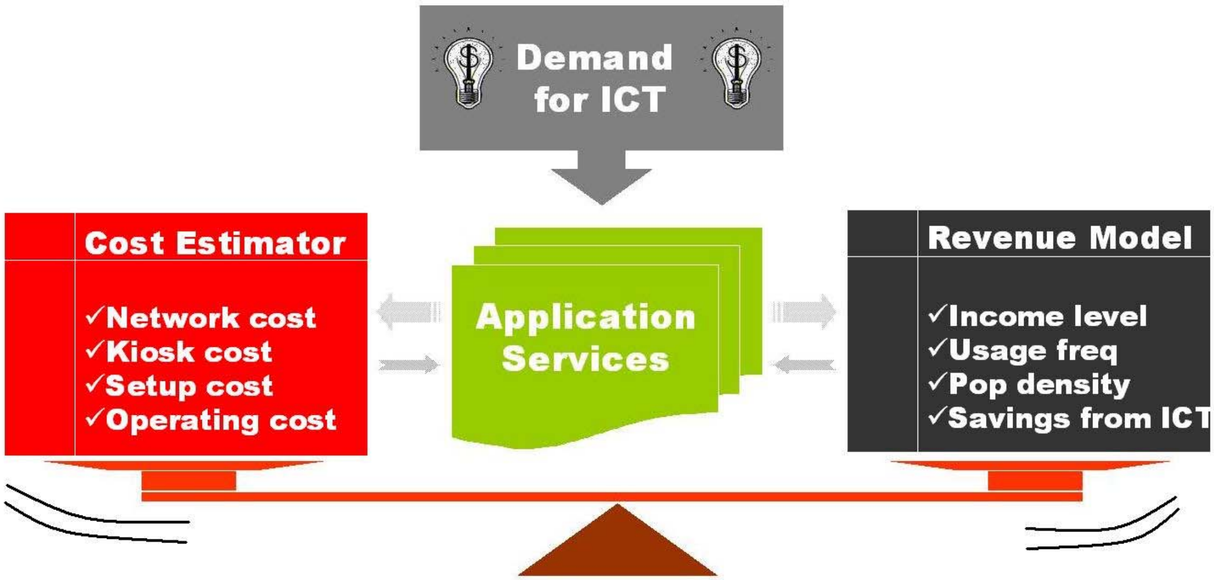
Given the characteristics of rural areas and the benefits of an asynchronous model at the application level, the research questions we addressed in this project were two-fold:

1) How to develop a quantitative method for selecting cost-effective data networks given project specific variables such as bandwidth requirements and village density?

2) In what ways can we optimize bandwidth utilization using asynchronous delivery methods?

3) What commercially viable business models can sustain these services?

The model we used to address these issues is depicted below:



The model is based on a need to balance costs and revenue, given a demand for ICT that is manifested in specific applications or services. In rural communities, we envision the best way to provide ICT applications and services is through village kiosks. We explore the concept of village kiosks in the business models section.

In the above model, we examined the cost of the network and kiosk, which includes the set-up costs and operating costs. Our revenue model is based on income level of potential consumers, the usage frequency, population density, and savings from ICT.

In additional to balancing cost and revenue, this model illustrates the bi-directional feedback mechanism determining application services. While multimedia applications could generate high revenue, the cost of setting up a high bandwidth network may be too expensive. Hence, the network budget constrains the types of application services offered. Yet if some high bandwidth applications (e.g. videoconferencing or music videos) are in high demand, then the marginal revenue may be high enough to offset the marginal cost. Thus, the array of ICT services is initially limited by the technology budget, but usage trends may uncover new services that could be profitably deployed.

In the next sections, a survey for network technologies is presented, a formula for network cost estimation is explained, and a sustainable business model is proposed.

II. Survey of Network Technology Options

Rural connectivity projects evaluate networks technologies based on many criteria. There are numerous metrics to consider: bandwidth, range, latency, energy cost, installation cost, and maintenance cost. The long list of technologies compounded by their associated metrics can easily overwhelm an evaluator.

Since technical standards are published and relatively unchanging, we compiled metrics for each network technology. A comparative survey enables project planners to skip the step of data gathering. The table of metrics for various network technologies can be found in Appendix B.

Types of Network Technology

The list of technologies is broken down into three categories: satellite, wireless local loop (WLL), and wired. Although satellite and WLL are both wireless, we separated them in order to consider the cost of towers.

A high level analysis reveals the pros and cons of each technology category:

Table 1: Pros and cons of various network technology options

	Pro	Con
Satellite		
LEO GEO (VSAT)	▪ Can reach remote, isolated areas ▪ Low infrastructure maintenance cost ▪ Bandwidth price decreasing in long term	▪ Expensive receiver dish/modem ▪ Current bandwidth cost is high ▪ High latency
Wireless Local Loop		
CDMA(fixed) CorDECT WiFi (802.11b) WiMax (802.16a)	▪ Medium to high bandwidth ▪ Infrastructure may already exists ▪ Easier to add kiosks	▪ Need to install towers ▪ Towers must be maintained ▪ Need line of sight
Wired		
Telephone Fiber-optic	▪ Telephone can utilize preexisting infrastructure ▪ Fiber optic is very high bandwidth	▪ Phone service unreliable ▪ Fiber-optic lines not yet available

As can be derived from the table, satellite technology is similar to wired technology because both require only a modem, whereas the WLL requires the setup of both the broadcasting towers in addition to modems.

A network evaluator also must take into consideration local factors when estimating the cost of a network. For instance, he/she must investigate any pre-existing network infrastructures. Piggybacking off preexisting CorDECT networks significantly decreases cost. An evaluator must also consider the local topology. The topology affects the range of WLL technologies; the range of the wireless technology decreases considerably in mountainous terrain. Lastly, operational bandwidth will be capped by the capacity of the Internet service provider (ISP). For instance, if the ISP capacity is 1 MB/sec, then a WiFi network broadcasts at only 1 MB/sec instead of the theoretical 11 MB/sec.

Cost Calculator

Project planners need actionable data points. A massive data table of aggregated technologies and metrics is informative, but an interactive cost calculator generates meaningful cost measures based on project specific inputs. Our model was developed to answer the question: how much would each different technology cost given 1) the bandwidth requirement (B), 2) the density of kiosks (V), and 3) the total number of kiosks (N)?

The first input, the bandwidth requirement (B), depends on the kinds of ICT services offered. The kiosk operator can estimate a kiosk's bandwidth requirement by grouping applications into separate tiers. Data transfer of different media content—text, image, audio, or video—determines the bandwidth requirement. For example, a VoIP requires 40kb/sec whereas videoconferencing requires 400kb/sec.

The second input, asks how many kiosks are in a square kilometer (V). It measures the density of the network. The density of kiosks determines how much wires or how many towers are needed to connect all the kiosks. In other words, whether the network is dense or sparse affects the infrastructure cost.

The third input, the total number of kiosks (N), determines the total cost of network equipment for kiosks. For example, if each satellite receiver cost $200, then five kiosks would add up to $1000.

Formula for the network cost calculator

The cost of a network can be represented as a function of the bandwidth requirement (B), density of kiosks (V), and the total number (N) of kiosks.

$$\text{Cost of Network} = f(B, V, N)$$

Furthermore, the cost of the entire network can be broken down into three distinct costs:

1. Infrastructure installation cost
2. Infrastructure maintenance cost
3. Kiosk cost

The infrastructure installation cost includes the cost of towers, wires, etc. The infrastructure owner will pay this amount to build the infrastructure. The infrastructure maintenance cost represents the monthly cost to maintain the entire network and includes the cost to connect all kiosks to the ISP; it also includes the maintenance cost rising from the kiosk modem. The kiosk cost is cost for kiosk owner. It represents the cost the kiosk owner will pay to make the kiosk connected to the network.

In the case of using a pre-existing telephone line, the kiosk owner can pay the ISP directly. However, for consistency of computation, this cost is included as a maintenance cost to the infrastructure owner. Lastly, the maintenance cost of the kiosk modem is included in the infrastructure owner's cost, since the infrastructure owner is likely to give support to those end modems.

Explanation of inputs and assumptions

Inputs into the cost formula can be classified into three types. The following table presents each type with its corresponding inputs:

Table 2: Three Types of Inputs

Type	Inputs
Hardware Configuration	Bandwidth per link, Connection per tower, Cost of tower, Radius, Cost of wire per Km, Cost of ISP center, ISP fee per bit, Monthly fee for connection, Cost of modem
Adjustment Factor	Bandwidth factor, Infrastructure installation cost factor, Infrastructure maintenance cost factor, Kiosk cost factor, Currency conversion
Case specific Parameters	Average distance to neighboring kiosk (D), Density of kiosks = $1 / D^2$ (V), Geographic factor (0 ~ 1) (G), Bandwidth requirement per kiosk (B), Total number of kiosks (N), Average degree of communication tree (K)

The hardware configuration type includes fixed-cost hardware and services. The inputs are objective and deterministic. For example, the cost of a modem can be estimated with high accuracy.

The second input type is the adjustment factor. The adjustment factor takes into account other costs that are not hardware costs. For example, in estimating the total installation cost, the adjustment factor would take into account administrative costs and moving costs. To simplify computation, rather than estimating each non-hardware cost separately, we represent the adjustment factor as a number to be multiplied against the hardware cost (we use 2).

If we focus on a particular case study, local factors must be taken into account to estimate cost more accurately. This brings us to the last input type: case specific parameters. This type includes the major inputs in network estimation. These parameters characterize the target area, and we need this information for that area to obtain the estimated network cost.

Detailed explanations for each input type are in Appendix C.

Explanation of network cost estimators

Our network cost estimations vary with the hardware needs of each technology. Among the three costs (infrastructure installation cost, infrastructure maintenance cost, and kiosk cost), the kiosk cost is the cost of a modem. The infrastructure maintenance cost is the ISP fee plus a percentage of the initial hardware value of the entire network (for instance, 1%). The infrastructure installation cost is the infrastructure hardware cost (towers, wires, etc). This cost is more complicated to calculate than the kiosk cost and infrastructure maintenance cost since it varies with the different technology types and their corresponding hardware needs. We use the following classification to aid us in estimating this cost.

As mentioned earlier, the network types we explored can be categorized into satellite, Wireless Local Loop (WLL), and wired technologies. However, they also can be classified depending on hardware needs: using existing infrastructure, tower based, and wire based. Table shows each type of network and examples of each type.

Table 3: Classification of Network Types

Network Type	Communication Technologies
Using Existing Infrastructure	LEO, MEO, GEO, CorDECT(existing), Telephone(existing)
Tower Based	GSM, CDMA(mobile), CDMA(fixed), CorDECT, WiFi, WiMax
Wire Based	Telephone, Fiber-Optic

We classify the technologies this way since each type shapes the network in the same way, even if the underlying technologies are different. We therefore have three different network cost estimators based on the classifications in Table 3.

Detailed explanations of the infrastructure installation cost and network cost estimators are in Appendix D.

Sample computation

As an illustration of a network cost estimator, we present one example of deploying a new CorDECT network. The following is the setting for the example.

D: average distance to neighboring kiosk = 4
V: density of kiosks = 1 / D^2 = 0.0625
G: geographic factor (0 ~ 1) = 0.5
B: bandwidth requirement per kiosk = 16,000
N: total number of kiosks = 100
K: average degree of communication tree = 4

Table 4: Sample Calculation for deploying a new CorDECT network

CorDECT Network Calculation			
Inputs		Outputs	
D	4	Infrastructure Installation Cost	$354,000
V	0.0625	Kiosk Installation Cost	$150
G	0.5	Infrastructure Maintenance Cost	$2,977
B	16,000		
N	100		
K	4		

In this case, we need $N/2V(GR)^2 = 100 / (2 * 0.0625 * (0.5 * 25)^2) = 6$ sites. (An explanation of this equation is in Appendix D). 6 sites are needed and 6 towers are needed. Since the bandwidth requirement is not very high, one tower can handle traffic in one site.

Each tower costs $25,000. Including the cost for the data center of $2000 (i.e. server) and one tower at the data center, the total infrastructure hardware cost is = ($25,000 * 7 + $2,000) * 2 = $177,000 * 2 = $354,000 (2 is the adjustment factor for the infrastructure installation cost).

The cost of hardware at the kiosk is $100; the kiosk installation cost is $100 * 1.5 = $150 (1.5 is the adjustment factor for the kiosk installation cost).

The infrastructure maintenance cost = [.01($177,000) + (.01($100) * 100 kiosks) + monthly ISP cost] * adjustment factor of 1.5 = ($1770 + $100 + $114) * 1.5 = $2,977. And total maintenance cost is $2,977 per month.

Graphs of Network Cost Sensitivity to Bandwidth and Density

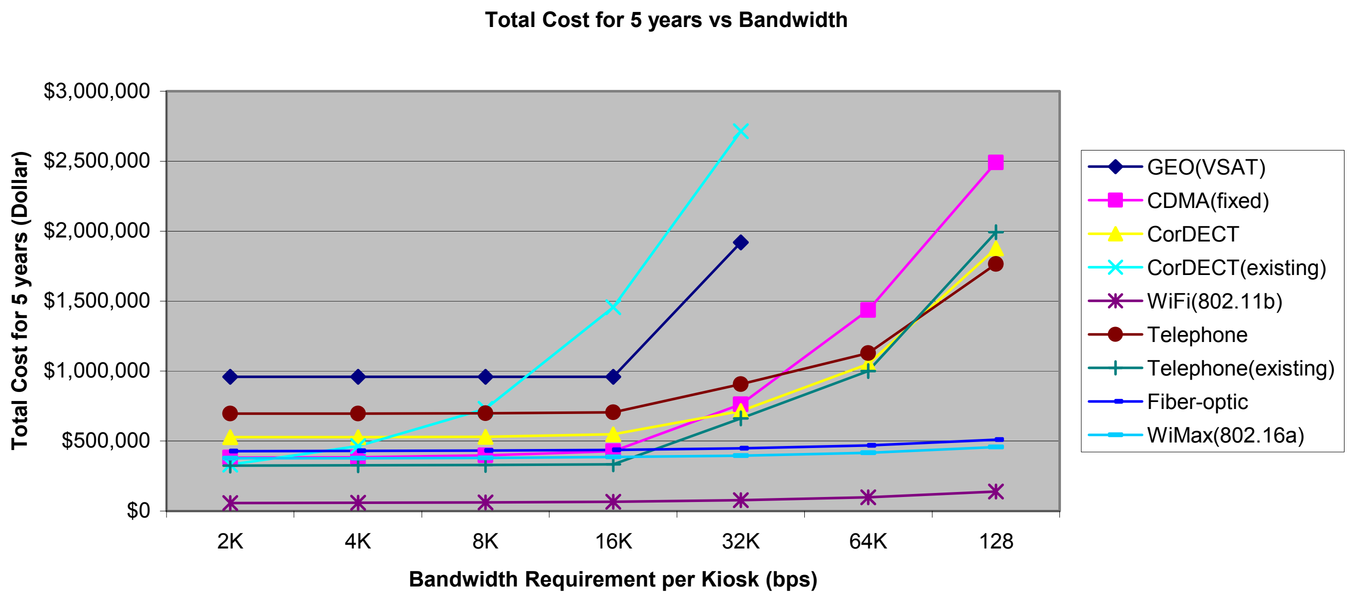


Figure 1: Bandwidth Requirement and Network Cost

The sensitivity of cost to bandwidth requirement per kiosk is shown in graph 1, assuming flat topology. The cost of LEO satellite is the highest. Using existing CorDECT is attractive when the bandwidth requirement is low. However as bandwidth increases, costs increase very quickly. Using existing telephone lines shows a similar trend, but at a lower cost. Fiber optics, WiMax, and WiFi are good choices for all bandwidth requirements.

WiFi is a good choice in this graph. The reason is that WiFi assumes directional antenna from towers to each village. Two facts are assumed: line of sight and manually tuned directional antennae. Line of sight to every village from the towers may not be true in severe geographic environments. In such circumstances, we need more sites, and this would lead to increases in cost. Manually tuned directional antennae also may have difficulty when scaled to thousands of villages. However, given our fundamental assumptions (rural area), WiFi is cost effective in low-density
areas.

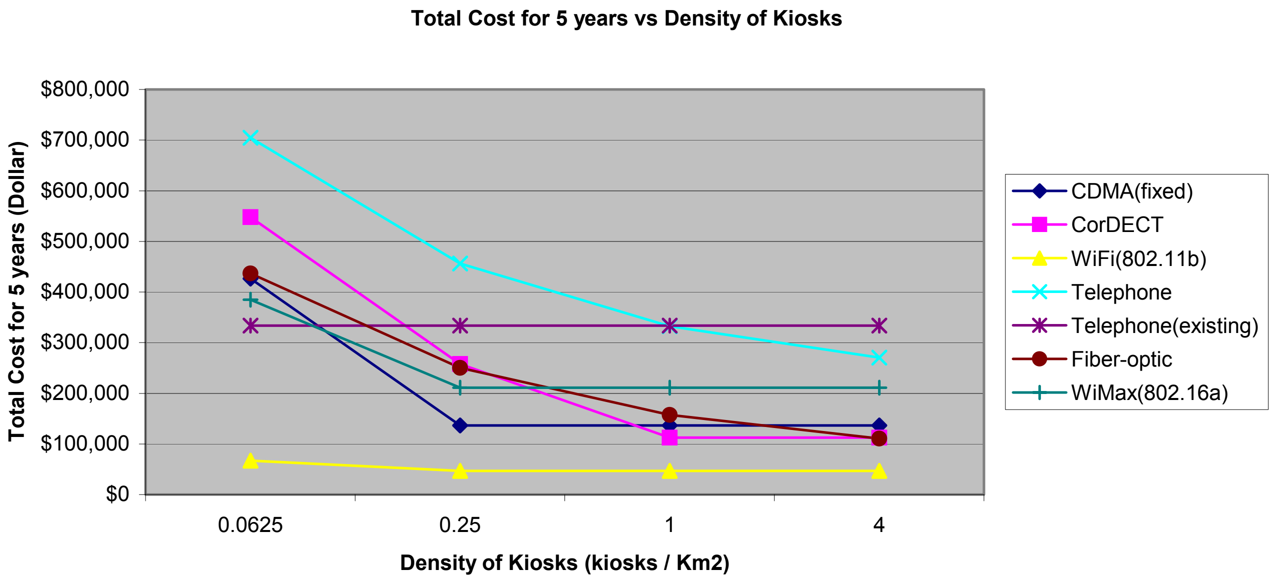


Figure 2: Density of Kiosks and Network Cost

As shown in figure 2, the density of the rural areas directly affects the cost of the network. Since the rural areas are sparsely populated, the cost of installing and maintaining infrastructure rises dramatically. For WLL technologies, more towers need to be built to relay connectivity to kiosks that are geographically spread out. In the case of wired technology, if the infrastructure does not exist already, then more wires would have to be laid to connect remote villages, thereby increasing cost of deployment. Satellite and exiting telephone networks are unaffected by the density of the network.

III. Business Models

<u>Business models we considered</u>

a. Government operated
b. Single-owner franchise
c. Collective franchise

Model	Pros	Cons
Government operated	• Start-up costs easier to acquire than via loans • Synergies across other government programs	• Less sustainable • Slow, bureaucratic governance not suited for ICT • ICT should alleviate government services, not burden strained resources
Single-owner franchise	• Entrepreneur has large incentive for success in upside case • Doesn't bear the risk of other entrepreneurs	• Least resources at disposal of owner • No collective pressure to perform • Difficult to scale with limited capital
Collective franchise	• Resources of group at the disposal of each kiosk • Best practices established and shared • Co-branded kiosks build trust in community • Share in downside risk • Easier to acquire loan	• Profit sharing may limit incentive to perform • Risk of spreading resources to thinly • Decision making process slowed

<u>Why Collective Franchise?</u>

A collective franchise model works best for rural connectivity for four reasons: scalability, collective responsibility, performance pressures, and community exchanges.
First, scalability is the process whereby other entrepreneurs could replicate a successful kiosk once they see the success of the model (or, on a unit level, grow the current kiosk). In a collective franchise, each kiosk can share resources and expertise, leveraging past success and accelerating the deployment of new kiosks. If the business model were a single-owner franchise, this might limit the amount of support kiosks provided each other because of the dynamics of

competition. Since infrastructure will often be shared, this might work against the deployment of new kiosks.
Secondly, a collective model provides greater leverage to secure a loan through shared responsibility. Clearly, a loan that is secured will be easier to acquire and can be for a larger line of credit. Yet securing a loan is often difficult in rural areas when the entrepreneur has little collateral. Thus, a collective franchise would allow increased capital to flow into the projects, secured by mutual assets across the franchise.

A collective loan is a key example of the third reason for our franchise model: peer-pressure to perform. Not only is there upside incentive to perform well under a franchise model (profits), there's also a downside incentive: losing loan collateral of the group. A team of franchisees working together, sharing risk and reward, creates the correct environment for achieving success. Peer-pressure is often a better tool for motivation than self-interest.

Finally, as was noted earlier, one of the important outcomes of a collective franchise model is the community of local entrepreneurs that can exchange best practices. Again, this might not be the case under a competitive model.

Why Kiosks?

From a business perspective, the Kiosk model fits best with a collective franchise. The most important reason for this is the fact that they can be easily replicated by other entrepreneurs with limited initial capital expenditures. Adding a new kiosk is relatively inexpensive since the data center is centralized. Each incremental kiosk does not have to bear the initial cost of infrastructure associated with deploying the first one.

Cost-Revenue Framework for Collective Franchise

Statement of assumptions

In assessing the costs and revenues we could derive, we want to make sure that on the one hand that our assumptions for costs are realistic and avoid the wishful myopia which minimizes costs or does not allow for overhead. That's why we doubled most costs incurred in setting up the kiosk to retain some slack in case unforeseen costs arise.

Beyond the cost numbers, we will work with NGOs, local women organizations and benefit from government support. Those factors, while they do not alter the figures, represent a real asset in that they will help mitigate the consequences of unforeseen obstacles.

To forecast the revenues we can derive from the services, we thought of two methods. The first one consists in taking villagers total revenues and allocating a percentage of the budget they would allocate to those services based on preference. The alternative method, that we actually applied with the contribution of Anil Jaggi, the Indian entrepreneur with whom we work, is to look at the cost of opportunity of any service, in other word, how much a villager would pay to get this service without the kiosk, and assume he would be ready to pay half this price to get the service through the kiosk. This represents a win-win situation where the kiosk owners makes money by providing useful services and where the client/villagers saves money by using those same services.

Finally, we performed sensitivity analysis to check how the loan repayment is affected by a shock on interest rates. Depending on the source of capital, interest rates can be astronomically high in developing countries. Also, in case of major economic crises, previously low interest rates can increase dramatically as a result of credit crunch (no more cash available to finance projects). The sensitivity analysis provides a sense for how immune to those external circumstances the franchisees will be.

Cost Breakdown

The cost model is broken into three parts: initial investment, cost of operations, and financing charges:

- Set-up costs
    1. Facilities
    2. Initial marketing
    3. Battery
    4. Computer hardware and software
    5. Training
    6. Modem
- Operational costs
    1. ISP/bandwidth
    2. Electricity and other utilities
    3. Human resources
    4. Software upgrades
- Financing costs
    1. Loan repayments
    2. Franchisee fees

Revenue Breakdown

Our revenue streams come from five sources: government services, business services, entertainment, education and tourism. Our categorization is somewhat arbitrary, and our purpose is primarily to provide a template and example of potential revenue streams as opposed to a set list of potential services. Each kiosk, given local needs, will deploy appropriate services.

Of critical importance, however, is to immediately offer services that will appeal to the masses and accelerate adoption and use of the kiosk. While “land record information” may be an important service for the local community, we believe that providing messaging, chat, imaging, and VoIP services will get people more excited about the new kiosks, thereby increasing the likelihood of their success.

Below is a snapshot from our revenue template (For the full template, see Appendix E). Each potential service is described by four metrics: the cost without ICT, the fee, frequency of use, and total revenue. The first column, the cost without ICT, drives the next three; the revenue generated by each kiosk will be a function of how well they can provide services that would otherwise be unaffordable or inaccessible. For example, accessing agricultural market data might cost as much as four times without ICT. This would drive the frequency of use and the willingness to pay for such a service. The prices should remain low at the beginning to encourage adoption of the new technology and to provide a margin of safety against any claim that ICT isn't as suitable for deployment of the service as the traditional means. Prices can then rise as the technology matures and becomes more stable.

Applications: Usage per Household per Month (in Rupees)				
	Cost (w/out ICT)	Fee per use (w/ ICT)	Frequency of use	Revenue
Business Services				
Livestock info	20	5	1	5
Agricultural market Info/data	20	5	4	20
DTP/Scanning/Designing	10	5	1	20
Sales/auction system	50	5	1	5
Weather report	4	5	4	20
Money transfer	40	20	0.5	10
Entertainment				
Communication with friend/family	100	NA	NA	0
Bus/Train Ticket booking	10	5	1	5
E-mail/VoIP/Chatting	NA	5	6	30

<u>Sensitivity Analysis and Impact</u>

To observe the dynamics of loan repayment, we set up a classic amortization table. Again, for the sake of security, we take our base revenues assumptions, divide them by 2, and run the center paying the conservative costs estimates. The schedule for loan repayment is as follows:

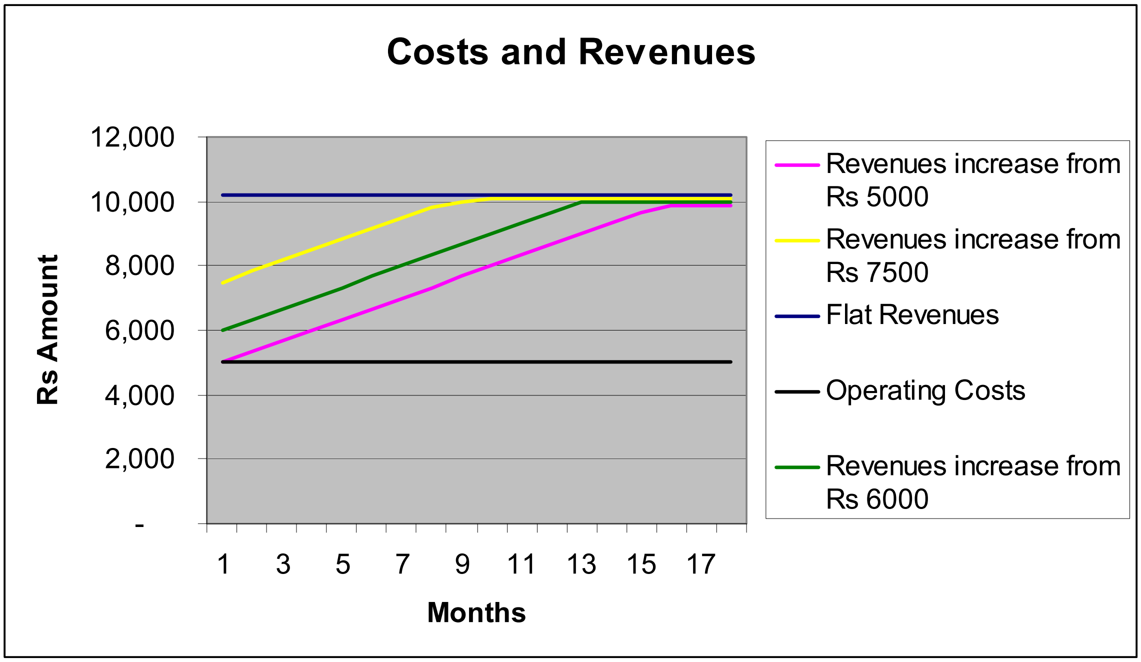
Loan Payment with revenue=10,000/Mth and I.R.=8%/Mth				
Month	Capital Due	Interests	Amortization	Payment
1	23,000	1840.00	3,160.00	5,000.00
2	19,840	1587.20	3,412.80	5,000.00
3	16,427	1314.18	3,685.82	5,000.00
4	12,741	1019.31	3,980.69	5,000.00
5	8,761	700.85	4,299.15	5,000.00
6	4,462	356.92	4,643.08	5,000.00

In this configuration, the initial loan is paid back after only 6 months despite high interest rates. The sensitivity to interest rates is not so high, since with a 3% monthly interest rate, the time needed to pay back is still about 6 months.

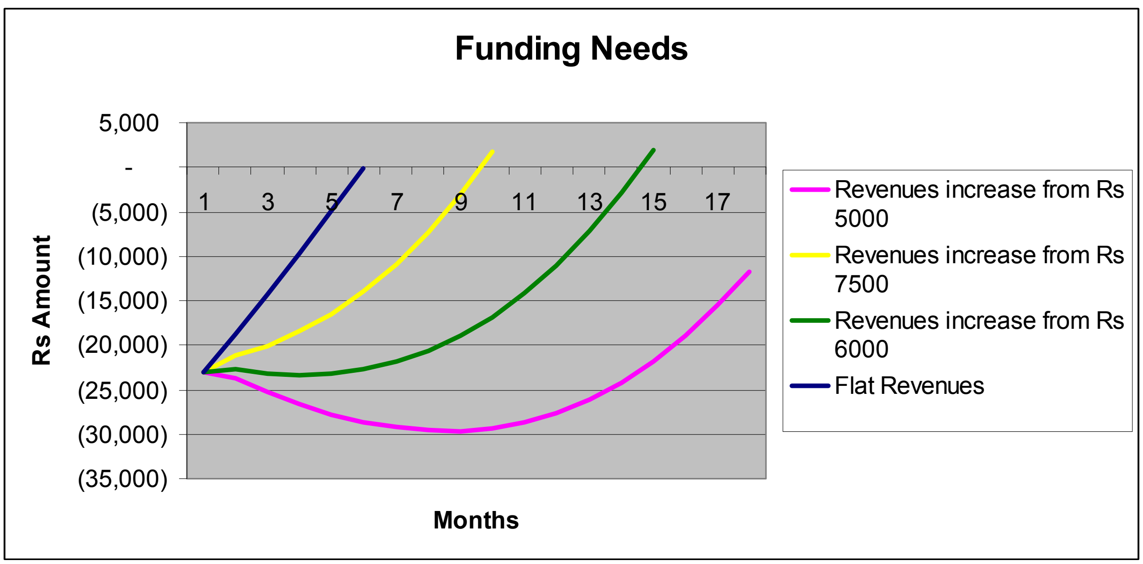
While the model becomes sensitive to interest rates when the business performance at inception is weaker than planned. A slow adoption of the services by the villagers may slow the revenues in the first phase. With the assumption that revenues would start at only 5000 Rs per month, barely covering the costs of operations, and reach 10000 Rs per month after 10 months of operation, the time to repayment increases from 6 months to 18 months. Also, the total capital needed increases from 23000 Rs to more than 29000 Rs.

Loan Payment with Increasing Revenues and I.R.=8%/Mth						
Month	**Revenues**	**Costs**	**Capital Due**	**Interests**	**Amortization**	**Payment**
1	5,000	5,000	23,000	690	(690)	-
2	5,000	5,000	23,690	1,895	(1,895)	-
3	5,500	5,000	25,585	2,047	(1,547)	500
4	6,000	5,000	27,132	2,171	(1,171)	1,000
5	6,500	5,000	28,303	2,264	(764)	1,500
6	7,000	5,000	29,067	2,325	(325)	2,000
7	7,500	5,000	**29,392**	2,351	149	2,500
8	8,000	5,000	29,243	2,339	661	3,000
9	8,500	5,000	28,583	2,287	1,213	3,500
10	9,000	5,000	27,370	2,190	1,810	4,000
11	9,500	5,000	25,559	2,045	2,455	4,500
12	10,000	5,000	23,104	1,848	3,152	5,000
13	10,000	5,000	19,952	1,596	3,404	5,000
14	10,000	5,000	16,548	1,324	3,676	5,000
15	10,000	5,000	12,872	1,030	3,970	5,000
16	10,000	5,000	8,902	712	4,288	5,000
17	10,000	5,000	4,614	369	4,631	5,000
18	10,000	5,000	(17)	(1)	5,001	5,000

To perceive the impact of difference initial business performance on the need in funds, we show how the revenue patterns change the funding needs.



From each of the revenues schemes, we can visualize the needs in funding:



The time needed to refund the loan or subsidies is critical to scalability: the quicker the franchisees can refund their loan, the sooner other entrepreneurs can open their franchise. Let's suppose our maximum amount allocated is Rs 30,000 at any time.

- If the franchisee revenues are Rs 10000 from inception, another franchisee can start after only 5 months of operations of the first franchisee (less than Rs 5000 still due after 5 months so more than Rs 25000 are available for another entrepreneur)

- If the franchisee revenues increase from Rs 5,000 as per our table above, the capital necessary for the next franchisee to loan will be reconstituted after 17 months only.

So in the first scenario, we can open 7 kiosks in 3 years with a capital of Rs 30,000; in the second scenario, we can open only 2 telecenters in 3 years with the same capital of Rs 30,000. As a conclusion, beyond the focus on execution to make sure that the services are accessible and reliable, we will focus on how to improve the adoption rate.

Some of the elements which will trigger viral adoption are the development of easy to use multimedia and local language based interfaces, and marketing strategy targeting young adults, to use them as early adopters and brokers of the technology for other segments of the population.

IV. Case Study: SEWAA

To test our cost calculator, we assisted a non-profit called Society For Environment, Wildlife Action and Awareness (SEWAA) to develop an implementation budget for their Multipurpose Rural Telecenter project. Through a series of phone interviews, we learned that the villages are located at the foot of the Himalayas. Their goal is to setup one village kiosk as proof-of-concept, and then replicate the model to up to100 kiosks.

As one goes higher up the mountains, the villages become more spread out and the cost of bringing connectivity to them increases. Our goal is to install one telecenter for a cluster of 5 to 20 villages. Fortunately, there are private phone-shops (PCO) in the region who offer pay per use telephone services. These entrepreneurs could expand their business to include a kiosk offering data services.

To determine the most appropriate network technology, we gathered three data points from the organization. The bandwidth requirement (B) is 40k/sec because they were willing to use asynchronous delivery methods to optimize bandwidth utilization. The density of kiosks (K) is .0625 per square kilometer. The total number of kiosks (N) is 100. After plugging in the three inputs into the cost calculator, we got these cost estimates. Total cost includes installation cost of infrastructure and 100 telecenters, and operation cost for 1 year.

Cost Estimation of Network Technology Options for SEWAA

	Infra install cost	Infra maintenance cost	Telecenter cost	Total cost
LEO	$ 0	$ 245,700	$ 25,200	$ 5,468,400
GEO(VSAT)	$ 0	$ 46,125	$ 1,125	$ 666,000
CDMA(fixed)	$ 5,504,000	$ 42,309	$ 600	$ 6,071,708
CorDECT	$ 6,954,000	$ 52,809	$ 225	$ 7,610,208
CorDECT(existing)	$ 4,000	$ 53,700	$ 225	$ 670,900
WiFi(802.11b)	$ 284,600	$ 2,714	$ 150	$ 332,168
Telephone	$ 352,800	$ 5,475	$ 2,400	$ 658,500
Telephone(existing)	$ 4,000	$ 10,989	$ 30	$ 138,868
Fiber-optic	$ 260,800	$ 2,685	$ 300	$ 323,020
WiMax(802.16a)	$ 2,104,000	$ 16,884	$ 675	$ 2,374,108

We chose to deploy the network over the existing telephone infrastructure since it is much cheaper than all the other technology options. Of course, the network cost is merely one component of the total budget for building and operating a kiosk. But at this stage planning, it gave us a range for the cost of building and operating the network.

On the revenue side, the revenue breakdown table was used to calculate the monthly revenue generated by each kiosk. The table in Appendix E shows that an average kiosk will generate about 400 rupees from each household. This amount should be multiplied by the total number of households using the service—which raises the critical issues of adoption rate. Both Sewaa and the research team emphasized that kiosk owner/operators must sensitize the villages to new ICT services. In order to get customers to walk into the door and pay for the services, we need to impress them with flashy technology. But in the long term, ICT has to contribute to their productivity by delivering information, communication, and entertainment that satisfied their needs.

Having figured out the cost of the network, the next step is to add in the rest of the operating costs such as: rent, utilities, training, advertising, loan repayment, and depreciation. Then we need to project monthly revenue growth by gauging the villagers' usage patterns. The breakeven point needs to be constantly re-adjusted to account for changes in the revenue trends as determined by adoption rate. Thus, the network cost calculator and revenue generation model better informs SEWAA's plans for establishing sustainable telecenters.

V. Conclusion

Rural connectivity projects fail to achieve sustainability because they do not cross the chasm separating intention and implementation. Oftentimes, under-utilized ICT equipment deteriorates into a pile of machines collecting dusk. Project planners lack rigorous methods for assessing the wide array of network technology options. At the kiosk level, entrepreneurs lack guidance and motivation for reaching revenue goals. These factors lead to underestimation of costs and overestimation of adoption rates, resulting in frustration for both service providers and end users.

Given low income levels among consumers, making an ICT solution affordable must be the first priority. Much enthusiasm surrounds the possibility of leapfrogging to WLL technology to circumvent the high cost of laying wires to reach end nodes. However, this survey sets forth two warnings: first, the local topology must be relatively flat and second, that installation and maintenance of broadcast towers significantly adds to cost. For instance, a heavy rainstorm could bring down the network for weeks if there are no technical personnel to fix the damaged tower.

Nonetheless, WLL is quite cost-effective. Among all the technologies, it is easiest to add kiosks to a WLL network. By comparison, equipment and bandwidth for satellite networks are so expensive that it should be used only in the areas that are unreachable by other means. Wired phone lines are slow and only as reliable as the telephone service. In the future, WiMax(802.16a) will be available as yet another WLL option. To facilitate the technology selection process, our cost calculator asks for case specific inputs—the density of kiosks, the total number of kiosks, and the bandwidth requirement—to estimate the budget for building the entire network.

In terms of business model, a cooperative franchise lends support and motivation to kiosk owner/operators. The biggest barrier to adoption is lack of awareness among the populace. The entrepreneur must drive usage by designing the user experience according to customer capabilities and needs. For example, an illiterate person would not sit down to type IM messages but would be impressed by a slide show of wedding photos. To build human capacity, the cooperative franchise structure enables access to capital, knowledge sharing and peer pressure to ensure that kiosk operators respond to customer demand.

Sustainability requires a steady stream of increasing revenue to offset the cost of installing and maintaining the network. Selecting the appropriate network infrastructure makes technology more affordable. Communicating asynchronously optimizes the utilization of bandwidth. Local entrepreneurs will collectively drive the adoption of ICT services with innovative service offerings and savvy marketing. In this way, scarce resources—equipment, bandwidth, and human resources—are efficiently allocated to maximize the utility of ICT to the poorest people in the world.

Appendix A: Examples of Asynchronous Delivery Methods

The concept of asynchronous communication needs concrete examples to illustrate its application and benefits. By asynchronous, we mean high latency. In technical terms, latency refers the delay that exists between sending and receiving data. At the user level, which is our focus, latency occurs whenever the requested information is not received in real-time. Thus, users experience latency as they surfing the web at a slow speeds since they must wait for web pages to be downloaded. As another example, communicating via email is asynchronous because there is a lag between sending the message and receiving a response from the other person.

Using the definition of latency at the user level, we came up with a list of sample ICT services that can be delivered asynchronously. During off peak hours, the kiosks should download popular content to a cache on the local hard drive.

ICT service	Asynchronous delivery method
Government forms	Many customers want the same forms; instead of download from the Internet every time, save the files to the hard drive
Offline browsing	Download entire websites for faster surfing offline
Newspapers/Blogs	Frequently updated content, such as newspaper articles or blogs, should be saved to the hard drive each morning
Matrimonial directory	Uploading a photo will tie up the computer; instead, batch uploading photos at the end of the day

These methods decrease the level of latency experienced by users. An added benefit is that if there is a queue of users waiting for the computer, having content cached in the hard drive would speed up the information seeking process. Consequently, the kiosk would generate more revenue (and decrease wait time), since it can accommodate more users during peak usage times without expanding bandwidth further.

Appendix B: Table of Network Technology Metrics

	LEO	MEO	GEO	GSM	CDMA (mobile)	CDMA (fixed)
Range (Km)	N/A [1]	N/A [1]	N/A [1]	30 [6]	30 [6]	30 [6]
Bandwidth (up/down) (bps)	4800 (*1) [3]		400K/40K (*2) [4]	14.4K [6]	13K [6]	> 13K [6]
Latency (s)	10m [1]	200m [1]	500m [1]	< 1m [6]	< 1m [6]	< 1m [6]
Rotation delay	15min [2]	2~4hr [2]	N/A	N/A	N/A	N/A
Frequency (Hz)			Refer 'Freq. Spectrum of Satellite' [2]	800M /900M/ 1800M/1900M	800M/1900M [7]	800M/1900M [7]
Cost (inst) ($)	modem 600~1000 (*1) [3]		modem 200~300 (*2) [4]	per user 701 (*3) [6]	per user 205 (*3) / 445 (*4) [6]	per user 290 (*4) [6]
Cost (month) ($)	70 (*1) [3]		99 (*2) [4]	43 (*3) [6]	26 (*3) / 40 (*4) [6]	35 (*4) [6]
Cost (min) ($)	0 (*1) [3]		0 (*2) [4]	0 (*3) [6]	0 (*3, *4) [6]	0 (*4) [6]

	CorDECT	WiFi (802.11)	WiMax (802.16)	Optical	Wired Phone
Range (Km)	25 [11]	38 (*6) [14]	50 (*8) [15]	N/A	N/A
Bandwidth (up/down) (bps)	35~70K [12]	11M (*7) [14]	70M (*8) [15]	1.0G	56K
Latency (s)	< 1m [12]	100~150u [14]	< 1m [est.]	< 1m [est.]	< 1m [est.]
Rotation delay	N/A	N/A	N/A	N/A	N/A
Frequency (Hz)	1.9G [12]	2.4G (*7) [14]	3.5G (*8) [15]	N/A	N/A
Cost (inst) ($)	tower 25,000 [11]	tower 200~850 (*6) [14]	tower 30,000 / modem 400~500 (*8) [16]	200 NIC [17] / 0.2 per meter [18]	end point 800 + line [11]
Cost (month) ($)	70 (*5) [13]	0 [14]	0 [16]	0	30~40 [11]
Cost (min) ($)	0 (*5) [13]	0 [14]	0 [16]	0	0

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*1 Orbcomm http://www.orbcomm.com/
*2 Directway http://www.direcway.com/
*3 Urban Kenya
*4 Rural Kenya
*5 Rural India
*6 With directional antenna
*7 802.11b
*8 802.16a

Appendix C: Detailed Explanation of inputs and assumptions

Table 1 Three Types of Inputs

Input Type	Inputs
Hardware Configuration	Bandwidth per link, Connection per tower, Cost of tower, Radius, Cost of wire per Km, Cost of ISP center, ISP fee per bit, Monthly fee for connection, Cost of modem
Adjustment Factor	Bandwidth factor, Infrastructure install cost factor, Infrastructure maintenance cost factor, Kiosk cost factor, Currency conversion
Case specific Parameter	Average distance to neighboring kiosk (D), Density of kiosks = $1 / D^2$ (V), Geographic factor (0 ~ 1) (G), Bandwidth requirement per kiosk (B), Total number of kiosks (N), Average degree of communication tree (K)

In the first type of inputs, the cost of ISP refers to the cost of building a data center. This data center will be used for handling asynchronous transfer of data to an end node. We assumed the data center will cost $2000, which is reasonable price for a well-equipped server machine. For ISP fee, possible bandwidth choices are discretely distributed (like 128Kbps or 256Kbps, etc). However, considering and getting cost for each case would be difficult. Therefore, $4 per 56Kbps rate is used.

In the second type of inputs, bandwidth factor means the ratio of actually obtainable effective bandwidth compared to theoretical maximum bandwidth. Here we used 0.4. Infrastructure installation cost factor means the ratio of total infrastructure installation cost to hardware cost. Total cost should include administration cost, personnel cost, installing labor cost, etc. Calculating all these possible costs would take too much effort, and cannot cover every possible source of cost. Therefore, we decided to multiply the hardware cost by a factor of 2 to get the total cost, assuming that those cost will be proportional to the cost of hardware. Kiosk cost factor serves the same purpose (the factor is 1.5). Infrastructure maintenance cost factor works in the same way, and is 1.5.

Case specific parameters are directly related to our modeling of hardware cost. Density of kiosks is equal to $1 / D^2$. Assume kiosks are located in lattice. Then one kiosk will occupy D^2 Km^2, which means within $1Km^2$, there exist $1/D^2$ kiosks. Geographical factor is used to incorporate constrains posed by the topology. Geographic limitation reduces the effective radius of wireless communication. Geographical factor is derived from the ratio of effective radius of wireless technology to maximum radius possible in plain land.

Determining the average degree of the communication tree is complex. We modeled communication network as a tree, with root being the data center. Then each node in a tree will have different number of children, which means diverse degree. It would be too complicated to consider a complete tree model. Therefore, we considered a single degree to simplified modeling.

Appendix D: Network Modeling and Link Level Estimation

Finding number of links to be installed is introduced first, which is simpler. When we install wires, installation cost is proportional to length of wire. It is reasonable to include installation cost here as a part of hardware cost, which is affected by case specific parameters. We assumed $0.1/m as installation cost (labor is $1/hour, and we can install 10m/manhour).

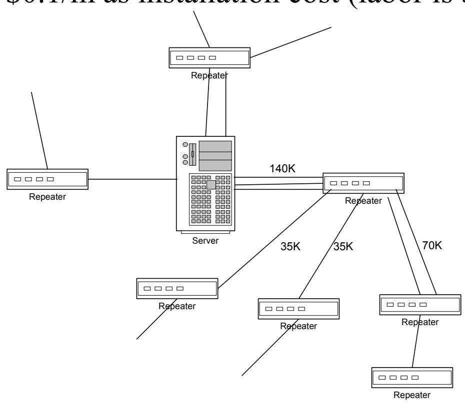

Figure 1 Estimation of Number of Links

Figure 1 shows method of estimating number of links. Assume each link can support 50Kbps of bandwidth (effective bandwidth). As we go up the tree to main data center, each link requires more aggregate bandwidth, since traffic merges. We formed this communication tree assuming degree to children is four. Then we calculated aggregate traffic in each link, and number of wires needed to handle the traffic.

There is an important distinction between kiosk bandwidth and link bandwidth. For example, kiosk will experience 56Kbps (theoretical limit) of bandwidth using one telephone line. However it does not mean copper wire in the ground will carry 56Kbps of data. Since copper wire in the ground will serve tens or hundreds of kiosks, the aggregate bandwidth of link equals the endpoint bandwidth multiplied by the link capacity of the wire.

If we have number of links to be installed, we can estimate the total hardware cost of the network infrastructure.

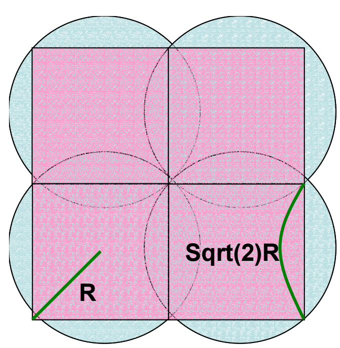

Figure 2 Coverage Model of Tower

For tower-based networks, we followed three steps. First, find the number of sites to build towers to cover entire area. Second, find amount of traffic that will be handled by one site. Finally using estimation method above for wired network, we can estimate number of links between each site, and number of towers in each site.

For the first step, we used the coverage model of tower as shown in Figure 2. If the range of tower is R (Km), one tower covers $2R^2$ (Km^2), and $2VR^2$ (kiosk). Considering effective range of radio by geographical limitation, one tower covers $2V(GR)^2$ (kiosk). We need $N/2V(GR)^2$ sites to cover every kiosk. Let S be number of site. Then, BN/S means the bandwidth requirement for each site. By building network of sites, we can calculate the number of links between two sites, and the total number of links needed. Total number of towers is more than total number of links. To consider this effect, a constant number is added to total number of links to get the total number of towers.

Appendix E: Application Revenue Breakdown Table

Applications: Usage per Household per Month (in Rupees)				
	Cost (w/out ICT)	Fee per use (w/ ICT)	Frequency of use	Revenue
Government Services				
Payment of utilities(water/phone/power/Insurance	10	5	1	5
Land record/Information	10	5	0.1	0.5
Birth/Death/Marriage/Domicile certification	10	5	0.001	0.005
Healthcare	0	0	1	0
Info on Various Govt/ Employment and development Schemes	10	5	5	25
Business Services				
Livestock info	20	5	1	5
Agricultural market Info/data	20	5	4	20
DTP/Scanning/Designing	10	5	1	20
Sales/auction system	50	5	1	5
Weather report	4	5	4	20
Money transfer	40	20	0.5	10
Entertainment				
Communication with friend/family	100	NA	NA	0
Bus/Train Ticket booking	10	5	1	5
E-mail/VoIP/Chatting	NA	5	6	30
CyberCafe	NA	5	3	15
Education				
Training	30	80	0.4	32
Employment search	20	10	0.5	5
Info on Higher Education				**197.505**
Tourism				
Tourist use (not local household)	NA	100	2	200
				397.505

1 dollar = 45.66 rupees

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