AsthaNet: Co-creating Network Solution for Socio-economic Development of Disconnected Communities

Abstract: We co-create networking solutions, called *AsthaNet*, to connect the disconnected rural communities with global resources. *AsthaNet* combines a bundle of modern technologies e.g., variant of ferry-assisted-DTN with TCP/IP, CDN; connecting disconnected Internet-of-Things (IoT), etc. *AsthaNet* provides autonomous and authentic solution to serve information demand which re-invents networking among rural communities (especially technically-less sound people) to enjoy quality localized contents with different dialects and accents. For socio-economic development of rural disconnected communities through ICT, *AsthaNet* adopts the concept of people's empowerment of Sir Fazle Hasan Abed and concept of people's development as freedom of Amartya Sen. As a result of this knowledge-based development, *AsthaNet* becomes the perfect blend of knowledge society using network solution to connect rural communities to develop with freedom and empower themselves to co-create solutions for surrounding social problems. This kind of empowerment is neither top-down nor bottom-up – it is horizontal development – a development with dignity.

Keywords: Delay Tolerant Network (DTN), Message Ferry, Content Delivery Networking (CDN), Internet of Things (IoT), Localized contents, People's Empowerment, Knowledge Society, Community Development.

1 Introduction

Socio-economic development in third world countries are strongly tied with rural developmentKillick (2000). At this age of technology, use of cutting age information and communication technology (ICT) in rural areas becomes indispensable means of rural development. There are many potential applications of information technology which can significantly contribute to socio-economic development as well as help developing promising ICT based social businesses. Such applications focus on social productions, consumptions and services. At present, significant rural development using information technology is no more an inconceivable function rather a sustainable and promising project, if such involvements respond to the local needs and re-adjust according to the prevailing knowledge of the rural areasChitla (2012). At this ICT age, getting proper information is treated to as one of the human rights. People of every line of works are in need of updated information related to their respective jobs. The people of developed countries have flawless, fast and reliable connectivity. But unfortunately, the scenario is not quite the same in most of the developing countries or the third-world countries, as the rural people are greatly deprived of information connectivity to access the ocean of information available in today's Internet. For example, according to the Bangladesh Telecommunication Regulatory Commission (BTRC)(November, 2016) *Bangladesh Telecommunication Regulatory Commission, BTRC* (2017), in Bangladesh, approximately 65% of rural communities are some how deprived of from information connectivity as well as information technology. According to World

Internet Statistics (2017) *World Internet Usage, Population Statistics* (2017) in Eritrea, Fiji, Niger, Chad, Congo only 1.3%, 1.5%, 2%, 2.6%, 3.8% of the countries' respective population are under Internet coverage. Besides, more than 94% of the total population in Western Sahara, Sierra Leone, Central African Republic, Madagascar, Somalia, Guinea-Bissau, Burundi are deprived of Internet connectivity *World Internet Usage, Population Statistics* (2017). Moreover, Intra-rural community communication, i.e., communication among neighbouring communities, for information and knowledge exchange also has a great impact on the journey to rural development. Utilization of information from neighbouring communities bring remarkable benefits in rural socio-economic development which have great potentials in rural community empowerment. We observed that there are some additional challenges in front of flourishing the ICT especially among rural communities. Most of the rural people as well as aged citizen are unmotivated to use the today's state of the art information and communication technologies (even if they have connectivity) due to two major issues: a) lack of suitable localized contents prepared in different localized dialects and accents, and b) rural people are not often technically skilled and/or literally sound to operate the modern devices and technology. These limitations are two more major challenges before rural communities accept the state-of-the-art smart devices and information system. We take special consideration of these two issues. Therefore, only providing the information facility is not enough for our targeted clients; rather, our prime objective is to bring the disconnected, technically and literally less sound rural people under the network coverage by providing an autonomous and authentic solution to collect and serve their information demand in a more convenient and convincing localized format. For example, providing existing information copying from the global Internet as it is may not be convenient to the targeted users, instead, the information requires to be converted to the localized format prepared by localized dialect and accent (in recorded audio or video format) for better understanding. Most of the rural areas in developing countries do not have enough infrastructure facilities to provide Internet services. Besides, it can be noted that most of the cases it is an expensive solution for the network service providers to establish networks in rough and harsh terrains of infrastructure-less remote and rural areas. The cost of establishing optical fibre links, broadband or other traditional networks is very high even for the government, non-government organizations or private network service providers in the third world countries.

Therefore, in such scenarios, a new, cost effective and efficient network architecture is essential for connecting these disconnected communities within themselves as well as with today's information technology. The remoteness of the concerned places causes delay in data communication because of discontinuation and disruption. Yet it is better to achieve desired contents even experiencing long delay than getting nothing. Hence, this is our cordial effort to put up the desire information towards our targeted clients by even tolerating long delays. Note here that in this proposed network real time data communication such as voice over or playing/streaming video may not well match.

From this motivation, we adopt a variant of Delay Tolerant Networks (DTNs) Cerf et al. (2007), which supports communication in a rather unorthodox way for the intermittent networks, where direct link at all times may not be available. This paper describes a practical implementation of a network architecture called *AsthaNet*[1] which is a ferry-assisted Zhao et al. (2004, 2005), Zhao & Ammar (2003) multi cluster DTN model Kabir et al. (2013), Sasabe et al. (2013), Kabir et al. (2012, 2011, 2010*b*,*a*, 2009), uses TCP/IP Jorgensen (2005) as communication protocols with the help of wireless connectivity enabled devices in an ad hoc manner. The short form of *AsthaNeT* is referred to as *ANT*[2]. As for the justification,

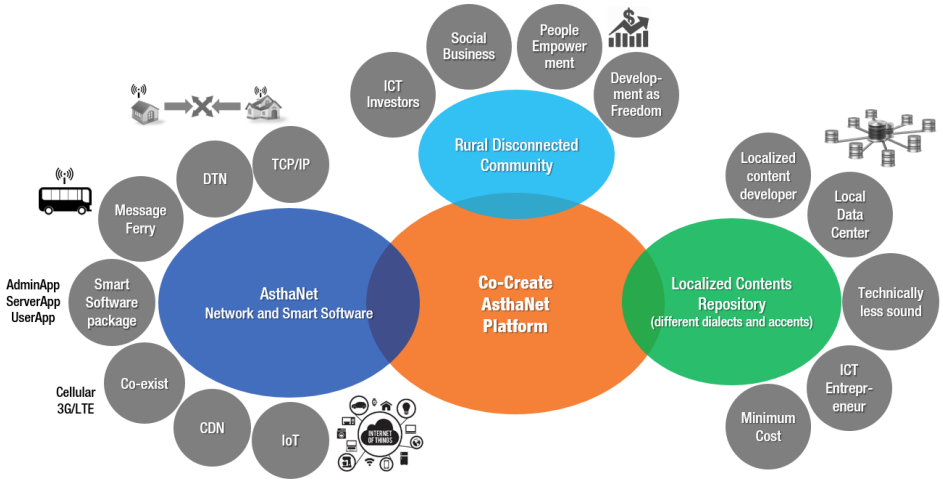

Figure 1 Co-creating *AsthaNet* Platform.

to ensure proper food supply and food storage, worker ants communicate, exchange and share information among each other as well as with other colonies. The working process of Ant communication network is similar to the multi cluster message ferry assisted DTN approach. The natural interactions among ants produce an entrusted network among the ants' colonies and we believe that our ferry assisted multi cluster *AsthaNet* works just like this Ant's network and builds trusted networks among the rural disconnected communities. *AsthaNet* also adopts Content Delivery Networking (CDN) technique Buyya et al. (2008), Lazar & Terrill (2001) to improve the data delivery latency. To implement our proposed model, a smart application/software package is essential to collect and serve the information demands of targeted clients in a convenient way. It offers user friendly interactions by taking technically-less sound rural communities into account.

The sustainability of such a networking system in any developing country largely depends on its commercial prospects and its contribution in rural socio-economic development. *AsthaNet* ensures a platform before many localized freelancer content developers to prepare high quality contents for disconnected rural communities. The preparation of localized version of existing data contents with suitable dialect and accent has high demand in this sector. This encourages the local rural social entrepreneurs to start their own business where they create on-demand and/or unique data contents, and finally sell those utilizing *AsthaNet* platform after proper quality checks. It provides a win-win scenario for both parties, i.e., technically unsound rural *End Users* (to receive easy to understand localized data contents) and the rural content developers (to create stable business).

It can be mentioned that people are more enthusiastic about participating in a community when they have certain degree of ownerships in any community activity. People's participation with their ownership is essential for sustainable development. People feel happy to be involved in the development process of their own community for any common benefit, and tries to sustain that development with common efforts, e.g., building schools for spreading education, creating religious worship places for spiritual gain, community market places or entertainment places for social gathering.

Therefore, to be informed with on-demand quality contents developed with localized dialects and accents, *AsthaNet* offers better possibilities for different communities to satisfy their knowledge needs. Thus, a knowledge society is established through knowledge-based development, that generates and disseminates knowledge to all members of a community to transform information into actionable insights and take effective measures for the their betterment Castelfranchi (2007). Similar to other community developments for the common purpose benefits, two kinds of outcomes are expected from *AsthaNet* platform: i) Experienced rural people willingly participate in quality content development to share their knowledge and experiences (each content is approved after proper quality checks), and ii) rural people willingly contribute their common efforts with their ownership to sustain the platform for local information sharing (note that quality content developers become one of the partners of ownership of *AsthaNet* and earn percentage of content's selling profit). Therefore, people's direct involvement in knowledge development with ownership ensures the sustainability and growth of *AsthaNet*.

Since one of the goals of *AsthaNet* is to develop a network platform for the infrastructure-less disconnected communities to be connected, *AsthaNet* is able to extend its connection to any other existing networks such as cellular mobile network (3G, 4G, LTE) or core information network of any country. *AsthaNet* is not an alternative network solution, rather a stand-alone solution that has flexible and compatible characteristics to co-exist with other solutions and share the benefits with each other. It may be noted that now a days a number of disconnected rural communities are getting connectivity by various commercial telecommunication companies. However, those are still expensive and un-affordable for majority of rural communities. Hence, by combining and sharing resources with the other existing telecommunication network system, *AsthaNet* offers a better cost effective solution (for example, in *AsthaNet* instead of connecting all *End Users* to the Internet, only *AsthaNet*'s sever directly connect to the Internet while the remaining *End Users* connect to the server to synchronize all users' data with free of cost or a minimum negligible maintaining cost).

Note that development of country's core networks or extension of mobile networks is a city-to-rural community approach and in third world developing countries, covering remote rural areas have less priority (even there is huge demand), which cause significant period and amount to practically implement to expect the benefit from it. On the other hand, *AsthaNet* is a rural community-to-city approach and is able to compatible easily with any developed network to provide the information to the door steps of the clients.

AsthaNet is also compatible with the ongoing state of the art projects for providing Internet access to rural and remote areas such as Google's project loon (uses balloons)*Wikipedia* (2017) and Facebook drones (unmanned solar powered airplane)*Wikipedia* (2017) to relay Internet connectivity to and from remote areas, or projects like Internet.org of Facebook*Wikipedia* (2017), Facebook zero*Wikipedia* (2017), Google free zone*Wikipedia* (2017) to connect everyone in the world to the Internet that are separated from major population centres by long distances or rugged terrain.

In addition, another notable feature of *AsthaNet* is that it creates trusted network among wireless connectivity enabled devices, therefore, with the help of cloud-storage, it is able to contribute to the Internet of Things (IoT)*Wikipedia* (2017), *Global Standards Initiative on Internet of Things* (2017). Hence, *AsthaNet* provides inter-networking of vehicles, physical devices, buildings and other items embedded with wireless connectivity enabled electronics, sensors, actuators in the rural disconnected areas to collect and exchange data to the IoT world.

AsthaNet co-creates a perfect network solution by means of a bundle of state of the art technologies such as message ferry assisted DTN, TCP/IP, CDN and IoT devices. The proposed smart application package of *AsthaNet* re-invents the ways for technically less-sound disconnected rural communities to enjoy quality localized data contents. Besides, *AsthaNet* adopts the concept of empowerment of Sir Fazle Hasan Abed, Founder and Chairperson of world biggest NGO, BRAC *Wikipedia* (2017), *Building Resources Across Communities, BRAC (NGO)* (2017), and the concept of development as freedom of another Nobel laureate Amartya Sen. As a result, all together, *AsthaNet* is a perfect blend of knowledge society using network solution to connect rural communities to develop with freedom and empower themselves to co-create solutions for surrounding social problems. This kind of empowerment is neither top-down nor bottom-up – it is a horizontal development – a development with dignity. Fig. 1 illustrates the co-creating concept of *AsthaNet*.

The remaining paper is organized as follows. Section 2 describes related works. The proposed network model is presented in section 3. The opportunities of *AsthaNet* as a milestone of socio-economic development in rural areas is focused in Section 4. Finally, Section 5 closes the paper with some concluding remarks.

2 Related Work

Many unorthodox and unique alternative schemes are proposed to connect the disconnected communities Yanggratoke et al. (2011), Raj & Chezian (2013). Many of them are tested or in the process of being tested, e.g., DakNet Pentland et al. (2004), Bytewalla Ntareme & Domancich (2011), Yanggratoke et al. (2011), 7DS Papadopouli & Schulzrinne (2001), SNC Doria et al. (2002), SWIM Small & Haas (2003), Motopost Naidu et al. (2008), PeopleNet Motani et al. (2005). DakNet Pentland et al. (2004) uses linux operating system based computers with Wi-Fi router attached to buses which travel among rural communities. Here, e-mails are downloaded to the rural communities and uploaded for transfer to the Internet or to other rural communities along the bus route. On the similar kind of bus network, a system of throwboxes Zhao et al. (2006), Banerjee et al. (2010) was implemented to extend the capacity of the DTN. Besides, KioskNet Guo et al. (2007) is a network of rural Internet kiosks that render data services in remote regions where vehicles with on-board computers transport and exchange the data between the kiosks and gateways connected to the Internet. On the other hand, cinema-in-a-backpack Galati et al. (2014) delivers educational and entertainment movies in remote rural communities similar to DakNet Pentland et al. (2004). Besides, TACO-DTN Sollazzo et al. (2007) is a content-based dissemination system composed of fixed and mobile info-stations that allow mobile users to subscribe to media contents for a period of time. Also, Campus bus networks designed to serve college commuters are proposed in Burgess et al. (2006), Zhang et al. (2007), Balasubramanian et al. (2007).

The conceptual goal of our work is somehow similar to those works. However, like our works very few of the existing works consider the technical unsoundness of targeted users while designing network solutions. Besides, most of the related works use the default bundle protocol (BP), which limits the mass adaptation with existing available affordable Wi-Fi equipped low cost and small smart devices, e.g., smart-phone and tablet. We use TCP/IP protocol suits for ad hoc networking during data synchronization between physically close devices within the wireless range. However, our system is fully adaptable with the BP and

is able to be customizable and convertible for BP in anytime. For better data delivery, our work considers the smart management of content delivery offered by CDN-server. Besides, in the rural and remote areas without network infrastructure, with the help of *AsthaNet* vehicles, physical devices, buildings and wireless connectivity enabled electronics, sensors, actuators are able to enter the world of IoT.

In our previous works Kabir et al. (2017, 2013), Sasabe et al. (2013), Kabir et al. (2012, 2011, 2010*b*,*a*, 2009), inter communities and intra communities communication between end users and administrative servers was investigated through three studies to comprehensively achieve effective data aggregation in ferry-assisted multi cluster DTNs. 1) Efficient algorithm to create groups of clusters and determining the location of Admin-nodes Sasabe et al. (2013), Kabir et al. (2012), 2) Efficient algorithm to obtain a suitable visiting order of message ferries for each group using the visiting order scheme Kabir et al. (2011) to minimize the average delivering time, and 3) Based on the self-organized data aggregation technique to autonomously select aggregators (cluster leader/head) in each cluster by accumulating bundles to a limited number of nodesKabir et al. (2013, 2010*b*,*a*, 2009).

Our current work is a continuation of our previous works and a cordial effort to practically implement the network solution for the infrastructure less rural disconnected communities.

3 Technical Overview

Establishing a traditional infrastructure across the rural and remote areas such as developing countries of sub-Saharan Africa or communication among islands in Maldives, is an expensive and time consuming solution. Therefore, Internet facility is offered by relaying global resources through an intermediary entity from a nearby town/city where Internet infrastructure is available. Although this solution compels the users to tolerate long delay to have their requested contents, yet this is the easiest and cost effective solution for those who do not have information connectivity. Thus, to connect the disconnected community with the global repositories, we aim to create a network model which has three prime entities: a) *End Users* at disconnected remote rural areas possess smart devices with suitable software installed and they are deprived of Internet facilities, b) a *Movable Server*, i.e., any traditional transport vehicle carrying smart devices with moderate storage and suitable software package travels across these disconnected remote rural areas, and c) an *Administrative Server* at a distant city with user database and administrative software package, which is directly connected with Internet facility to process the information demand of the *End Users*.

With this motivation, we aim to develop an efficient and cost effective network solution, i.e., *AsthaNet* which is a combination of DTN and CDN where TCP/IP protocol suite is used for data transmission mechanism. *AsthaNet* employs wireless connectivity enabled smart devices that work in a store-carry-and-delivery manner. The network model of ferry assisted multi-cluster DTN is illustrated in Fig. 2. It consists of several isolated remote *clusters*, e.g., city/town and rural communities, where there exist several *nodes*, e.g., *End Users*/servers. At a city, a message ferry, i.e., *Movable Server* synchronizes latest data contents with *Administrative Server*, then stores and carries the data. *Movable Server* delivers the data contents through two way synchronization when it is within the wireless range of *End Users* in a rural community. Since we are considering a challenged network situation with

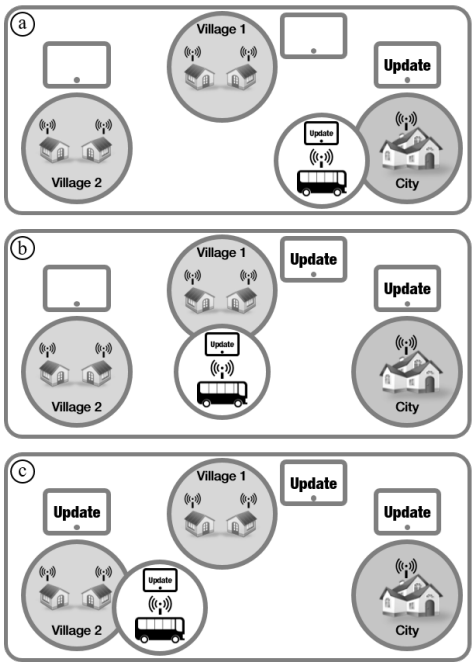

Figure 2 Ferry assisted multi-cluster DTN. a) At city, message ferry synchronizes latest information contents with *Administrative Server* (having access to global and local information content pools) when both of them are within wireless transmission range. b) When message ferry is within wireless transmission range of *End Users* in village 1, they synchronize latest information contents. c) In the same manner, information contents of village 2 and hence, all the rural communities are synchronized and updated accordingly. This procedure continues in the successive round trip.

disconnections, real-time data communication e.g., voice over or playing/streaming videos, is not suitable for *AsthaNet*.

The detail of the concept of *AsthaNet* is discussed as follows.

3.1 Delay Tolerant Network (DTN)

DTN is a unique network architecture that supports communication in heterogeneous networks and allows data transfer in situations where traditional networks are incapable and physical end-to-end connectivity is not present Cerf et al. (2007). Similar to the basic building block of the Internet, i.e., TCP/IP, the fundamental technique of DTN is Bundle Protocol (BP) Scott & Burleigh (2007). The big difference between BP and IP is that, while IP assumes a more or less smooth pathway for packets going from start to end point, whereas, BP has the capabilities to store the data and allows data communication even under inferior communication environments, e.g., disconnections, disruptions and discontinuation. The DTN architecture uses in-network or node-level storage to allow data, i.e., bundles in the DTN, to be stored for arbitrary lengths of time, unless the forward path is available. This clearly differs from the IP model where IP packets must be forwarded immediately, otherwise, dropped.

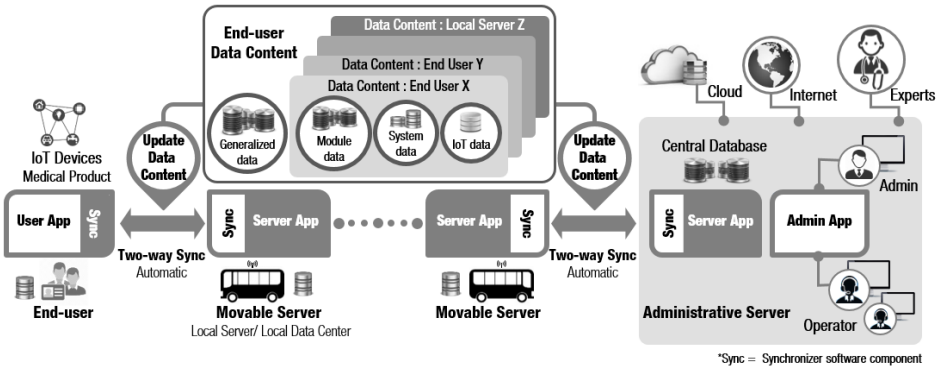

Figure 3 Overview of AsthaNet Software Platform.

3.2 Adoption of TCP/IP in AsthaNet

Our specific and variant of DTN scenario differs from the standard DTN scenario used for challenged network, where the network has to rely on the opportunistic connectivity. In the contrary, in our ferry-assisted multi cluster DTN scenario, the locations of distant rural communities, i.e., clusters are permanent and the *message ferry* (*Movable Server*) travels round trips in the predefined path to communicate *End Users* in each rural community. Here, *End Users* know the path and data delivery point of *Movable Server* as well as where and when to collect data from them. While the wireless ad hoc networking technology connects the physically closed *message ferry* and *Administrative Server*, it establishes the reliable end-to-end connectivity between them. Then, the *message ferry* moves to one rural community and again it establishes the reliable end-to-end connectivity between the physically closed *End Users*. Thus, when we consider data communication between source (*Administrative Server*), in nearby city to destination (*End Users*) in a distant rural community, the overall network does not have any end-to-end connectivity. However, during data synchronization between *message ferry* and *Administrative Server* or between *message ferry* and each specific *End User*, they establish a reliable end-to-end connectivity between them, with the help of TCP/IP. Thus, *AsthaNet* employs TCP/IP and utilizes high performance preferences of TCP/IP. Moreover, it is advantageous in the current scenario, because most of the state-of-the art smart devices use TCP/IP as a communication protocols. However, our system is fully adaptable with BP and *AsthaNet* is able to customizable and convertible for BP in anytime with suitable software upgrade. The existing software platform of *AsthaNet*, showing the relationship between different entities, is illustrated in Fig. 3.

The network entities and features of *AsthaNet* are discussed as follows.

3.3 End User

In *AsthaNet*, *End User* is referred to as an individual possessing a wireless devices, e.g., smart phone, tablet or laptop in a disconnected community. These wireless devices use Wi-Fi technology to establish ad hoc network within the transmission range. Wi-Fi technology is considered because of its higher data transfer speed, ability to connect multiple users and relatively better radio signals. Besides, for our rural *End Users*, the Wi-Fi enabled small smart devices, i.e., smart-phones or tablets become the best choice due to cheaper

price (more affordable to general people day by day) and easy user interface/operations, along with other additional attractive features such as better processing specification, better software customization option and openness for upgrade. Wi-Fi enabled wireless devices use ad hoc Network technique to connect with each other within the transmission range. Here, Wi-Fi Direct[3] technique improves the simultaneous connectivity among the devices with less technical setup and without any wireless access point (WAP).

Besides Wi-Fi technology, the popularity of *Long-Term Evolution (LTE)* is also raising as a dominant connectivity technology for high-speed wireless mobile communications. Because of its increased capacity and speed, the technique of *LTE-Advanced* for Device-to-Device (D2D) and Machine-to-Machine (M2M) are being adopted by many wireless mobile connectivity providers as well as IoT service providers. Many newer versions of Android-based smartphones, iPhones and iPads are compatible with LTE. On the other hand, *Bluetooth 5*, the latest version of Bluetooth, is another promising technology for wireless connectivity among mobile devices. *Bluetooth 5* supports longer range, faster speed, larger broadcast message capacity, improved interoperability and coexistence with other wireless technologies.

3.4 Administrative Server

At urban area or city, a desktop or laptop computer with sufficient storages and computing capacities serves as *Administrative Server* in *AsthaNet* which has access to local repositories and/or global repositories i.e., global Internet, and archives localized information contents. *Administrative Server* is responsible for collecting, storing and processing, and is also responsible for carrying and synchronizing (delivering) the requested information demands to *End Users*, with the help of *Movable Server*. *Administrative Server* acts as the ultimate destination for all requested information demands. By taking into account technically-less sound rural people, *AsthaNet* provides an efficient user software with an easy and convenient user interface that requires fewer interactions. As, all the information requires to be localized format with local language (in recorded audio/video format) for better understanding, some expert human entity is required to process the user requested information demands (recorded audio/video or text format). With the help of *Movable Server* after carrying the user-data, i.e., information demands at the administrator server, a human entity serves as *Administrator* (*Admin* in short) to manually process all users' information demands with the help of the *AsthaNet*'s all controlled *Admin* software (*AdminApp*) and Server software (*ServerApp*). Table 1 describes different software components and databases of *AdminApp*, while Table 2 describes the overview of the different software components and database of *ServerApp*. If *End Users* increase, *Admin* may employ one or more additional *Admins* and/or one or more job specified *Operators* to assist processing the requests of the targeted *End Users* efficiently. Here, *Administrative Server* provides services similar to *Call Center*[4] service, where human entity helps to process the user requested data instead of user's telephone call.

3.5 Movable Server

As mentioned above, in *AsthaNet*, *Message Ferry* Zhao et al. (2004, 2005), Zhao & Ammar (2003) acts as *Movable Server*. *Movable Server* contains a copy, i.e., replica, of user database and server software that synchronizes the requested data of *End Users* with those of *Administrative Server*. *Movable Server* stores and carries the data and then travels to the disconnected destination rural community. Finally, it synchronizes the stored data with

Table 1 Overview of software components and inner databases of *AdminApp*.

Software Component	**Functionality**
Component:	
AsthaNet Admin Tool	Controls the at-a-glance projection and management of all activities and latest data contents of each *End User*.
User Content Updater	Updates the user data contents as instructed by the *AsthaNet Admin Tool*.
Content Analytics Tool	Recommends the *AsthaNet Admin Tool* with one or more relevant domains of contents service in relation to an *End User* on a given context.
Admin Task Manager	Provides platform for monitoring and managing multiple *Operators*.
Content Indexer	Provides platform for indexing/tagging of updated data with appropriate keywords and stores in Content Index table.
Frequent Queries Finder	Determines the contents those are required to be preserved in the CDN database for future use.
Content Distribution Manager	Prepares updated user data contents of multiple clusters/rural communities/groups of *End Users* for different *Movable-Servers*.
AsthaNet Route Manager	Sets routes for multiple *Movable-Servers* visiting multiple disconnected clusters of *AsthaNet End Users*.
User Account Approver	Manages the *End Users*' registration for *AsthaNet* services.
User Payment Handler	Manages the user billing for *AsthaNet* services.
Admin Application Manager	Manages the behavior of different components at *AdminApp*.
Central Storage Manager	Manages the storages of *Central Database* and *CDN Database*.
AsthaNet Web-based-Tool	Provide suitable environment to interact *AsthaNet* cloud-storage.
IoT Service Manager	Interacts with associated *AsthaNet* cloud-storages to process IoT-data.
AsthaNet Analytics Tool	Analyses the *End Users* interaction with *App* and represents them on dashboards in the form of graphs.
Database:	
Central Database	Contains multiple structured tables which describe Central Dataset, user profile and activity details, and network service details.
Central Content Index Table	A table belonging the Central Database used for quick information retrieval by *Admin*, where each row describes the content category and multiple relevant key words as tags/indices for a particular information content of Central Dataset.
CDN Database	Contains related tables, views describing the information contents of *AsthaNet* CDN services (frequently asked information contents with associated *CDN Content Index Table* and local messaging information contents with *LMS User Detail*).

those of the designated *End Users*, which may cause collection of newly requested data from *End Users*. This procedure will continue in the successive round trip. Server software requires no human interaction, i.e., it autonomously synchronizes user software as well as administrative software when they are physically close.

Table 2 Overview of constituting software components and inner databases of *ServerApp*.

Software Component	**Functionality**
Component:	
802. 11 Connection Handler	Handles wireless connection establishment and data communication between participating Application software.
Synchronizer	Synchronizes the most updated data content between participating applications.
CDN Service Module	Ensures content delivery networking for connected application.
Database	
Server Database	Database containing the data content and user identification details of *End Users* belonging to a partial network covered by the particular host *ServerApp*.

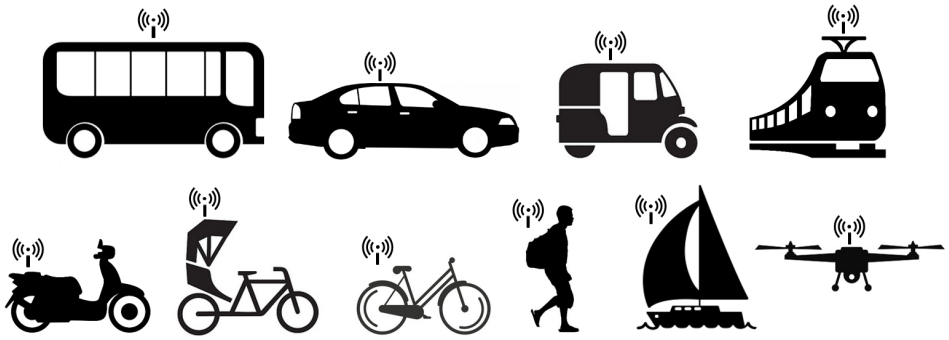

Figure 4 Traditional transport vehicle equipped with wireless enabled smart devices consider to be used as Message Ferry i.e., *Movable Server* or Local Server.

Any traditional motor or non motor vehicle engaged in Intra-rural community transportation is eligible to be used as *Message Ferry*. Thus, utilization of available resources in disconnected communities is promoted, which significantly reduces the implementation cost. However, dedicated vehicle (message ferry) ensures faster data transfer and improves reliability. As in Fig. 4, each vehicle is equipped with the wireless connectivity enabled device with a suitable *AsthaNet* server software installed and offers autonomous connectivity and synchronization by carrying out of its scheduled tasks without any human interaction. Here, the power consumption of the device is minimized by utilizing a solar panel on vehicle's top so that un-interrupted data delivery is facilitated in case of power failure or any disaster scenario. *Movable Server* is supposed to stay close to *Administrative Server* for a moderate period of time to synchronize all *End Users*' data. Therefore, the *Administrative Server* is installed near a parking garage, gasoline station or any place where the Message Ferry can stay moderate period of time. During the travel, the Message Ferry makes several stops for certain amount of time at different designated stoppage, e.g., general bus stops, gathering points at different communities, community markets, school, hospital, business center, to pick and drop passengers. In that meantime, Message Ferry synchronizes respective data content with the respective *End Users*. The synchronization is possible due to the *ServerApp* software that is installed on the *Movable Server*.

Figure 5 Example of different Services modules of *AsthaNet*.

3.6 AsthaNet Services at a glance

In *AsthaNet* scenario, for efficient data delivery performance and to ensure quality of service, all *End Users* require to be registered free of cost in *AsthaNet*. The services experienced by the *End Users* are classified into two generic categories, a) general information data service for all *End Users* without cost, and b) value-added modularized data service or *Service Module* for designated *End Users* with a very nominal fee. In addition to the general information data service, the *End Users* are offered to activate more than one modularized data services, such as Entertainment Module, Farmer module, Student module, Rural Woman module, Community Development module, HealthCare module, Businessman module and IoT Coordination Module. These services can be activated simultaneously in the same device and are designed to serve rural people of various line of works. Fig. 5 illustrates the different value-added Service Modules of *AsthaNet* for the initial phase.

With a free registration process each *End User* is provided with general information data services such as general farming info., electronic newspaper, government info., local events, general health tips, weather forecast and general education information. This is treated as one way push service where explicit user request for content is not supported.

On the other hand, value-added *Service Module* supports on-demands services, i.e., *Customized-Query Service*,[5] for information demands through two way push-pull service. On the basis of user's interest and technical soundness, *Customized-Queries* are represented in a suitable format (one-click "Hold-and-Record" audio/video or text format). The concept of service modularization is preferred for reducing the unnecessary network traffic. Note here that, the activation of modularized services and enabling explicit requests require an activation process through few more terms and condition with a very nominal fee (for manual data processing, responding and maintenance/operation cost).

Adopting CDN approach to our multi cluster DTN model is the key technique for improving data delivery performance. The more detail of these services is discussed in the remaining section. *AsthaNet* also facilitates two more value-added *Service Modules*

Table 3 overview of constituting software components and inner databases of *UserApp*.

Software Component	**Functionality**
Component:	
802.11 Connection Handler	Discovers *Group Owner* of WI-Fi direct group and establishes and supports secure data communication.
User Synchronization Handler	Provides necessary supports for synchronizing updated data contents
Customized-Query Manager	Assists the preparation of user queries in prescribed format.
User CDN Service Manager	Manage and help visualizing all CDN services with the help of *ServerApp*.
User Account Handler	Provides interactive platform to create and manage user accounts for rural community services.
User Configuration Handler	Configure the updated configuration profiles to modify user interface and service access.
User Storage Manager	Provides storage management platform for User Database.
User Interface Manager	Provides interactive user interface and visualizes the user contents through appealing visualization tools.
Database	
User Database	User data content containing only latest data.
User Index Table	Associated User Index Table for User Database.
CDN Index Table	Associated latest *Guided-Query* keywords, tags and registered *LMS User Detail*.

named *Guided-Query Service (GQS)* and *Local Messaging Service (LMS)* with significantly reduced delivery delay.

3.7 Multi user Data management of AsthaNet

Since from *Administrative Server* information is not delivered to the designated *End Users* immediately, storage management in all devices in *AsthaNet* is an important issue. Here, *Movable Server* synchronizes data with *Administrative Server*, then carries and synchronizes data again with *End Users*. *Administrative Server* and *Movable Server* carry Server software (*ServerApp*) and, between them, the one that stores the latest data acts as Server. On the other hand *End User* carries User software (*UserApp*) and act as client. Once a connection is established, synchronizer component at Server software compares the contents present at both of the connected storage devices and synchronizes data with latest data and deletes old data. *AsthaNet* multi user data management system categorizes the stored data sorted into general information data for all *End Users* and value-added modularized data for *End Users* activating one or more Service Modules. The value-added data is ensured restriction from unauthorized access and deleted by *Administrative Server* from memory after delivery to ensure privacy and reuse of storage. It can be noted that frequently asked (FA) information keep remain for future use (discussed in later section). These information contents are preserved for future use during a predefined period, which are able to be instantly accessed without connecting to the *Administrative Server*. Table 3 describes the software components of *UserApp*

3.8 AsthaNet Remote Administration

In *AsthaNet*, all contents (both general information and value-added modularized data) are stored and sorted based on meta data structure (fetched and presented in category wise/directory-wise/folder-wise for different activities). Data of each registered *End User* is stored in user folders created according to the device's MAC-ID and/or user-ID while generalized data are stored in category-wise, e.g., news, weather and government information.

Each application folder in each registered device contains a sub-folder of general information data and sub-folders of one or more modularized data. It also contains configuration/preference data of the user interface and dashboard of the user software, i.e., *End Users* internal data resources and service profiles. Each file format is either text, images, audio instructions and recorded video (read out recorded audio files for text information for the less educated, aged citizen or blind *End Users*). The folder contains only the latest information. Older data inside the folder is updated (or deleted) during each synchronization with *Movable Server*.

User interface of *AsthaNet* application software hides the folder from the general *End Users*, i.e., technically-less sound rural *End Users*, to make it very user friendly or ease to use. After opening the application, each *End User* are able to see (access) only the application's dashboard that shows the latest information from the generalized data folder and specific modular folder. Dashboard is designed by big icons and animated/audio/video instructions.

Note that after one round trip, the central database of *Administrative Server* contains the same replica (copy) of all registered End User's folders created with the designated devices' MAC-IDs and/or user-IDs. Hence, if *Admin* at *Administrative Server* updates, adds or deletes any file inside any folder of specific *End User* or change the configuration and preference file of the user interface and/or dashboard, during the next synchronization the folders and files are also updated in the *Movable Server*. Then, each *End Users* software is updated while *Movable Server* is physically close to that *End User*. By this manner, even if there is any update of software, *End User* does not need to manually do anything, i.e., device just synchronizes with the latest data (while deletes old) and the dashboard shows the latest information.

In this manner administrator is able to have full control over all the folders and files in the network. Though there is no end to end connection, administrator is able to control all activities through hop-by-hop control. This is a huge advantage when dealing with the technically-less sound, less educated, aged citizen or blind *End Users* in such kind of distant and detached rural community. However, advanced users, e.g., students are offered to activate advanced manual control of some folders, e.g., downloading requested video or audio files to the external memory, e.g., micro SD card.

Remote administration of user activities from a central administrative node facilitates many user flexibilities in distributed network. Though the establishment of centralized control in any infrastructure-less distributed network is not a trivial case unlike in any structured distributed network. *AsthaNet* remote administration has this powerful feature of centralized user control in infrastructure less distributed networks. This centralized user control remotely facilitates a Server to change or configure *End Users*' internal data resources and service profiles. Hence, it reduces intensity of manual configuration or troubleshooting from *End User* side and thus, brings significant flexibility and ease to them.

Note that this is not a real time data communication, hence, some delay during update of data requires to be compromised.

The administrative control is achieved through the admin software (*AdminApp*) present on the *Administrative Server.*

3.9 Local Server and Local Data Centers

In some cases, desired recipients of *End Users* may be unavailable at the designated premises, due to out of transmission range of *Movable Server*, which results in reduced delivery ratio. In this kind of incident, *AsthaNet* utilizes the concept of *Local Server* to elevate the data delivery ratio. Any dedicated *End User* can act as *Local Server*, if he carries the similar hardware and software profile (*ServerApp*) of a *Movable Server*. In any rural community, *Local Server* is the representative of a set of *End Users* and usually stays in a general meet point. The *Movable Server* connects and synchronizes data with *Local Server*, each of which is responsible for storing the data of a group of *End Users* within the rural community and deliver them to each *End User*. This is sometime advantageous when travelling time of *Movable Server* is limited and/orwhen demand of number of *End Users* increased significantly.

It can be noted thatany ICT entrepreneur with a dedicated similar hardware and software profile of a *Movable Server* is eligible to be a *Local Server* with a minimum service charge. A *Local Server* receives information contents belonging unavailable *End Users* and delivers those following the same procedure once they reach the transmission range. Moreover, any *Local Server* also displays important information on an electronic projection board in small rural community shop if available. Thus, people from disconnected communities get important and general public information without having their own devices even.

With the hope of improved service gain and organized management, *AsthaNet* also establishes multiple *Local Data Centers* at different geographic points in a single rural community. Each *Local Data Centers* acts as static *Local Server* with similar hardware and software profile, and is dedicated in serving one or more particular Service Module. For example, *Local Data Centers* placed at schools provide *Student Module*. Similarly, at the hospital and the agricultural office, Health Care module and Farmer module are available, respectively. Such kind of distributed Service Modules increase network efficiency and data management performance of *AsthaNet*.

AsthaNet uses different categories of *Local Data Centers* such as a) Local Data-center for Business, b) *Local Data Center* for Agriculture, c) *Local Data Center* for Education, d) *Local Data Center* for Entertainment, e) *Local Data Center* for Health-Care and f) *Local Data Center* for Rural Woman. For better data delivery performance in this kind of infrastructure-less community, in a rural community *Local Server* collects user data contents associated with their respective *End Users* from *Movable Server* at predefined delivery point. The *Local Server* then carries those user data contents to the corresponding *End Users* or *Local Data Centers* based on the user default delivery point within the rural community accordingly. Finally, *End Users* synchronize their requested contents with appropriate *Local Data Centers* or from *Local Server* according to their needs and convenience. Section 4 discusses many prospective uses of these *Local Data Centers* which have significant impact on elevating socio-economic condition in remote rural communities. Fig. 6 illustrates the detail data flow among all network entities.

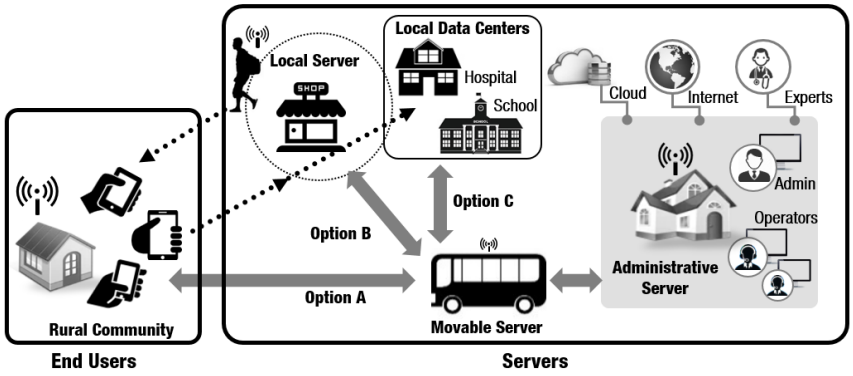

Figure 6 Data flow among all network entities in *AsthaNet*.

3.10 Content Delivery Networking (CDN)

To serve the frequently asked information demands, CDN Buyya et al. (2008), Lazar & Terrill (2001) technique is applied in *AsthaNet*, which greatly reduces the data delivery delay and thus boosts up the data delivery performance. In *AsthaNet*, the *Movable Server* primarily acts as a *CDN Server*. In the similar manner, *Local Server* and *Local Data Center* can also act as local CDN Server. *CDN Server* instantly synchronizes the specific requested data contents with the connected devices if the requested data are available in the local CDN-server.

In this kind of infrastructure-less delayed network scenario, CDN service ensures faster data delivery from multiple distributed locations. A number of distributed CDN servers, e.g., *Movable Server*, *Local Server* and *Local Data Center* cache the frequently asked popular contents, which are synchronized with *Movable Server* and are already indexed in a specific Content Index Table[6] with appropriate tags/key-words by *Admin* at *Administrative Server*. These indices support the quick retrieval of requested information contents and thus a CDN-server delivers the requested information demand instantly using advanced seeking on indexed data content. Retrieving resources from a localized cache can significantly reduce delivery time of the overall system.

If any frequently asked information contents requested by *End User* that used to be served by the Administrative Server is available in a CDN-server, then the connected CDN-server redirects the request from the originating site's server, e.g., *Administrative Server* to CDN-server, e.g., *Movable Server*, *Local Server* and *Local Data Center*. It then serves instantly and delivers the cached content. During each synchronization, all CDN Servers synchronize frequently asked information contents along with updated *Content Index Table*.

In the initial stage of *AsthaNet* platform, the CDN services for two categories[7] of explicit user requests are considered: a) The *Guided-Query Service* (GQS) for frequently asked data contents, i.e., user can provide queries through text format following prescribed instructions and choosing specific keywords from drop down menu and serve instantly, and b) *Local Messaging Service* (LMS) among registered *End Users* of *AsthaNet* (CDN-server at *Movable Server* stores and carries text messages, emails, recorded audio and video messages of registered *End User* (source), then distribute them to other registered *End User* (destination) located within the rural community or located in other communities/cities without communicating *Administrative Server*). Here, CDN-server re-directs the role of

Table 4 Constituting software components and inner databases of *CDN Service Module*.

Software Component	**Functionality**
Component:	
Guided Query Manager	Manages the CDN service for serving guided user queries
Local Messaging Service	Executes necessary operations on behalf of *AdminApp* to enable local communication among *End Users*.
CDN-service Manager	Instruct the Synchronizer component of *ServerApp* to re-synchronize instantly if requested query is available and prepares appropriate log file containing the details of CDN service usages by each *End User*.
Database	
CDN-server Database	Carries frequently asked data contents (along with associated Content Index) (cached from *AdminApp*) and LMS data content (cached from *UserApp*).
CDN Index Table	Carries LMS registered user list and *Guided-Query* keywords, tags cached from CDN Database.

Administrative Server and acts as an *Administrative Server* if any requested service is possible to serve *in the attached Server*, which reduces delivery delay and data latency significantly in this kind of intermittent scenario. During validating and updating the Content Index Table, *Admin* assigns the Keywords required for GQS. Besides *Admin* also updates the list of all registered *End Users* for LMS. These keywords and registered *End User* List along with the Content Index Table are updated during each synchronization with *UserApp* (with the help of *Movable Server*). Note here that *Guided-Queries* of CDN Service Module and *Customized-Queries* of value-added modularized services are different. *Guided-Queries* are being served instantly (upon availability in CDN server), when queries are requested by choosing keywords (based on available CDN data contents). On the other hand, *Customized-Queries* are on-demand user's queries requested by direct user input i.e., through one-click "Hold-and-Record" audio/video or text format. *Admin*/operator in Administration server manually process *Customized-Queries* and respond accordingly. The data flow among *AsthaNet* network entities for serving these services are depicted in Fig. 7. Table 4 describes the system diagram and software components of *CDN Service Module*.

3.11 AsthaNet Cloud-storage

AsthaNet Administrative Server is attached with a *cloud-storage* to ensure better scalability, reliability, security and performance by sharing the information resources among geographically distributed *AsthaNet* systems, e.g., *AsthaNet* Administrative-servers with respective local resources. *AsthaNet* Cloud-storage is a cloud-storage service providing scalable and flexible cloud-storage and related management services for multiple Administrative-servers. *AsthaNet* information contents are stored, modified and retrieved over the Internet through this cloud infrastructure service. *AsthaNet* purchases suitable cloud-storage services, i.e., Microsoft Azure, Adobe Creative Cloud, JustCloud, PCloud and Zoolz from storage service providers (SSPs) with appropriate terms and conditions. Thus *Admin* can capitalize the power of collective resources to enhance the service performance of *AsthaNet* services.

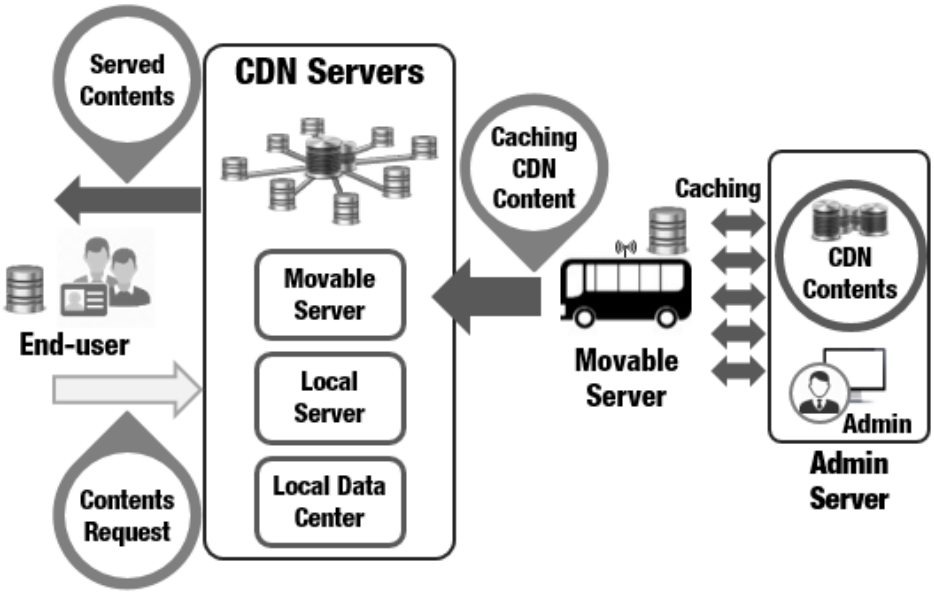

Figure 7 Data flow among *AsthaNet* network entities for serving CDN services. If requested content is available in local CDN server, the content request is redirect and is served immediately without the involvement of Admin-Server.

3.12 DTN and IoT service coordination

AsthaNet provides a trusted network platform among wireless connectivity enabled devices of IoT system in the rural disconnected areas with a ubiquitous approach to monitor and control the surrounding environment of rural communities. The inter-networking of physical devices, buildings and other devices embedded with wireless connectivity enabled electronics, sensors, actuators in the disconnected areas, can contribute to the world of IoT with the help of *Movable Server*, *Administrative Server* and *AsthaNet* cloud-storage. The assurance of reliability and resilience of deployment of large-scale IoT systems in this kind of disconnected infrastructure-less areas are very challenging. In such scenarios with rural disconnected communities, *AsthaNet* aims to create a network ecosystem among smart devices, i.e., Wi-Fi enabled *AsthaNet* Servers and high performance modern sensors/actuators (referred to as *IoT-devices*) to relay the IoT-data to the appropriate IoT service solution providers through *AsthaNet* cloud-storages. These IoT service solution providers manage a wide range of required IoT applications.

The IoT-devices with limited form factor communicate among themselves with low range radio employing protocols defined by IEEE-802.15.4 standard Molisch et al. (2004), which focuses on low-power, low-speed and ubiquitous communication. On the other hand, the Wi-Fi enabled *AsthaNet* Servers (*Movable-Servers*/Local Servers/Local Data Centers) use Wi-Fi radio interface and follow protocols defined by IEEE 802.11 standard Crow et al. (1997), which focuses on high power and high data-rate communication. Hence, few adoptions are required for communicating between devices following two different standard protocols. On account of this fact, instead of employing these adoptions to every IoT-devices,

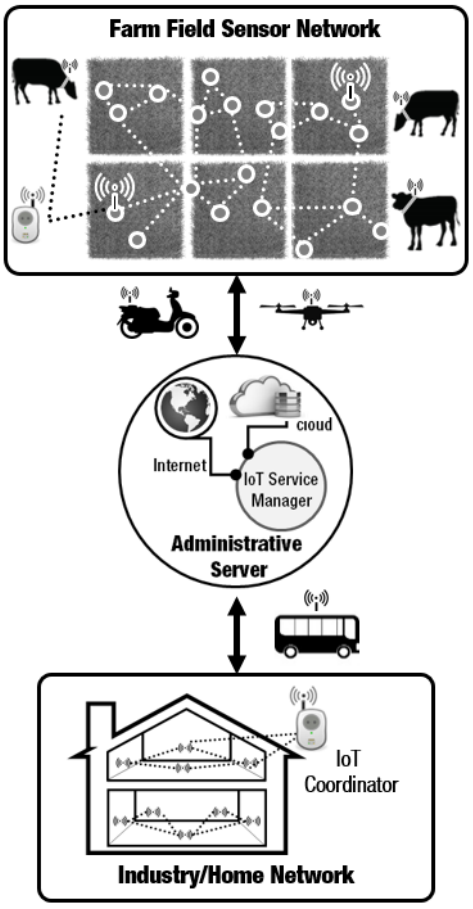

Figure 8 Topological structure of IoT networks on *AsthaNet*.

only IoT coordinating device (referred to as *IoT Coordinator*) placed at the boundary of the IoT networks adopts the modification and enables the interoperability. Thus, this *IoT Coordinator* takes the role of gateway*Wikipedia* (2017) and shuttles traffic between these two different networks. Table 5 describe the protocol stack and the software components used by *IoT Coordination Module* of *UserApp*, respectively.

To bridge between these two networks, *IoT Coordinator* has built-in dual radio interfaces: a) Low range radio interface that communicates among IoT networks following 802.15.4 standard, and b) Wi-Fi radio interface that communicates with the Wi-Fi enabled *Movable Server* following 802.11 standard. In *AsthaNet*, a smart device, such as smart-phone/tablet or laptop, with suitable hardware (dual radio capability) and conversion software acts as *IoT Coordinator*. On the software side, the adaptation is accomplished by *IoT Coordination Module*, which is a service module of *UserApp*, the software module present in *End Users'* devices.

It is worthwhile to mention that besides IEEE 802.15.4 (ZigBee), LTE is gradually developing its immense prospect for the high performance IoT devices. Therefore, the development of LTE embedded IoT devices, e.g., home appliance, utility meters,

Table 5 Constituting software components and inner databases of *IoT Coordination Module*.

Software Component	Functionality
Component:	
802.15.4 Connection Handler	Establishes network connection and support compatible data communication with subordinate IEEE 802.15.4 compliant devices (IoT-devices).
IoT Data Representer	Adopts appropriate modification at data format for compatible data representation at destination *App*.
IoT Data Manager	Classifies the received IoT-data into appropriate category and manages the storage of *IoT Database*.
IoT/Actuator Manager	Executes necessary operations based on given policies to implement the instruction given on updated IoT-data.
Database	
IoT Database	Carries classified latest IoT-data of subordinate IoT-devices.

automobiles, indoor cameras and health monitoring devices, is supposed to increase within a few years. In addition to LTE, *Bluetooth 5* is another prospectus wireless connectivity enabler to promote IoT experience by empowering simple, faster and effortless interactions across many connected IoT devices with its longer range.

As a representative of a group of geographically closed IoT-devices, *IoT Coordinator* collects and stores the IoT-data as a cluster-head. It then synchronizes the latest IoT-data with *Movable Server* when they can communicate with each other. *Administrative Server* synchronizes IoT data with *Movable Server* and transfer them to the designated cloud-storages for IoT-solution or for providing manufacturer of the IoT devices to interact. Fig. 8 illustrates the network structure of IoT network in *AsthaNet* network model.

4 Contribution to Socio-economic Development through ICT

Sir Fazle Hasan Abed, Founder and Chairperson of world biggest NGO, BRAC *Wikipedia* (2017), *Building Resources Across Communities, BRAC (NGO)* (2017) said that *"People are poor because they are powerless. We must organize people for power. They must organize themselves so that they may change their lives."* Besides Nobel laureate Professor Muhammad Yunus, Founder of Grameen Bank *Grameen Bank, Bank for the Poor* (2017) said that *"The oneness of human beings is the basic ethical thread that holds us together."* Another Nobel laureate Amartya Sen described in his book, Development as Freedom Sen (2001), that *"Development consists of the removal of various types of unfreedoms that leave people with little choice and little opportunity of exercising their reasoned agency."*

With these motivations, *AsthaNet* aims to achieve its ultimate goal through two ways: i) to be connected is power and ii) to be trustfully informed is power. As a result, connected and perfectly informed rural communities develop themselves with freedom and empower themselves to co-create solutions for their surrounding social problems.

Freedom to access the information network and developing it as the people's own network empower people and solve many basic needs. Traditionally, when we live in a community or in a society, we are automatically in a social network that gives us many supports for survival and other needs. Traditional social gatherings and connections are not digital and generally confined in smaller geographic areas. Here, there is less possibility for

most of the people to access new knowledge of other communities. *AsthaNet* can unlock the possibilities to connect to issue-based-networks based on trust, and to share and solve their problems together. People will feel the strength of cooperative actions and happiness of co-creation.

The utilization of information only even from neighboring communities is remarkably significant to majority of the rural people. It has great impacts on the journey to rural socioeconomic development. There exists many potential ICT based applications for rural community people, which require only local information. On the contrary, majority of the rural areas in developing countries do not have adequate network infrastructure to provide ICT based services. According to World Internet Statistics (2017), less than 3% of the countries' respective population are only capable of getting ICT services in Eritrea, Fiji, Niger, Chad and Congo. Less than 6% of the total population in Western Sahara, Sierra Leone, Central African Repuplic, Madagascar, Somalia, Guinea-Bissau and Burundi are under the Internet based ICT services *World Internet Usage, Population Statistics* (2017). The fact is that in most of the cases it is an exorbitant solution for network service providers to install the networks in such infrastructure-less remote and rural areas. Hence, *AsthaNet* play a vital role in connecting them within themselves and with the global ICT services.

The *AsthaNet* platform creates significant economic and social benefits by giving a trustworthy network platform in the infrastructure-less remote communities. As the platform progresses and expands, there are numerous growth opportunities through the creation of social business and jobs within communities.

AsthaNet can take a great role in the journey of developing socio-economic condition in disconnected rural areas. Slight modification through different modularize services in *UserApp* and proper utilization of spatially distributed *Servers*, i.e., *Movable Server*, Local Servers and Local Data Centers, are offered to present high-impact and fine-grained information contents concerning their needs in different rural sectors. Providing the appropriate information at appropriate situations acts as a great catalyst in lifting socio-economic conditions if it focuses on rural production, consumption and services.

When people are together for a specific cause, they also start to solve other basic problems like health, education, housing, livelihood, food production, clothing, security, etc. This kind of specific knowledge is stored digitally as *Community Development Module* in *AsthaNet*, which is considered as education for specific demands and complements to the traditional nation-wide common education system. People with similar kind of needs in other communities or other countries are able to utilize the similar knowledge through *Community Development Module* in *AsthaNet*. During their development process, they can also improve the contents of the module by adding their own additional knowledge. Each community has different needs and requirements and has different progress characteristics to be developed. This kind of development requires specific local knowledge and direct participation of the local community. This localized, specific and on-purpose knowledge sharing through *Community Development Module* creates a platform for all the communities to develop themselves according to their own needs with full of trust. Therefore, this section explores many prospective opportunities of *AsthaNet* at different sectors, especially for the basic rights of human being, such as shelter, education, health and food (agriculture) of disconnected rural areas, which can together promote the socio-economic condition.

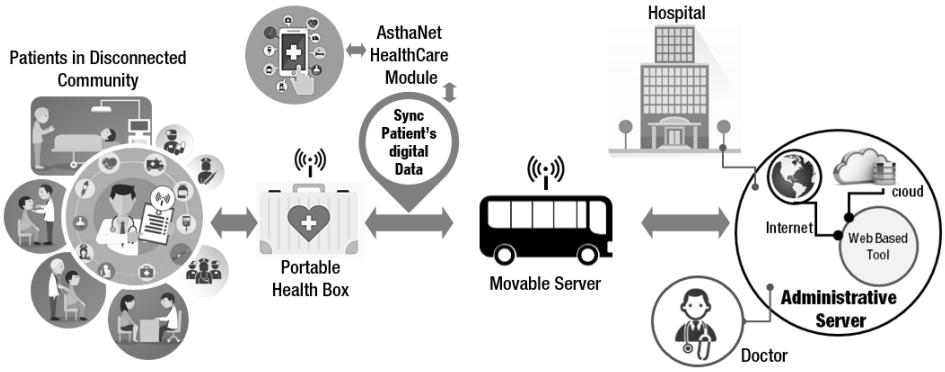

Figure 9 The disconnected patient/healthcomplex//hospital uploads the clinical health status of critical patients in the form of digital data with the help of portable Healthbox employing *UserApp* with HealthCare Module to a *Movable Server*. The health status is then delivered to *Administrative Server*, where the experts doctor are connected. The experts doctor then examines the symptoms and prescribe accordingly, which are delivered in reverse way.

4.1 Health and Sanitation Sector

Adequate healthcare facilities are one of the basic needs for the development of socially live style but they are lack in the majority of remote rural communities of developing countries. People in such situations are deprived of effective medicare facilities and sometimes they also experience lack of primary health and sanitation. Therefore they are easy prey to different malicious and seasonal diseases, whereas a little concern can prevent all these in a great extent. Most of the reasons behind this deprivation is inadequate infrastructure facilities and remoteness of the disconnected concerned places.

4.1.1 HealthBox

Rural hospital authorities sometimes feel the necessity to consult with specialized doctors about critical patients. They upload the clinical health status of critical patients onto *Local Hospital Data Center*. The health status may include a specific vital sign, such as blood glucose, heart electrocardiogram and a variety of indicators for distant patients. Here, these processes can be accelerated by diagnostic testing smart medical products with wireless connectivity.

As discussed in our previous work Kabir et al. (2017) and as illustrated in Fig. 9, the remote healthcare services at remote disconnected health-complex/hospitals are offered to extend their services to a portable digital healthcare box. This healthcare box has a basic diagnostic testing equipment with a wireless facility and a smart *End User* device with *UserApp* including *Healthcare Module*. The disconnected *End User*, e.g., patient, paramedic, health-complex or hospital, is able to effectively prepare medical investigation data by means of this portable digital healthcare box for collecting and carrying the patient's primary healthcare information in the form of digital data.

Local Hospital Data Center preserves the digital healthcare information and synchronizes it with *Administrative Server*, with the help of *Movable Server*. Administrator synchronizes it with the *AsthaNet* cloud storage for ensuring the direct access to the authorized healthcare service provider at urban/city. Once the experts check the symptoms

through *AsthaNet Web-based-Tool* and prescribe accordingly, the health status is then delivered in a reverse way to the respective *End Users*.

4.1.2 Raising Health and Sanitation Awareness

General information data service provides the general symptoms of common diseases and their cures to all *End Users* with the coordination of different *Local Servers at Hospital*. The information is even projected on electronic display if available at *Local Hospital Data Center*.

4.2 Community-wide, City-wide and Nation-wide Savings and Housing network

4.2.1 Saving Networks

When people are together for the cause of the development, they start creating networks among themselves. Saving money/asset/resource is one of the essential requirements for any development and people creates saving networks to achieve this successfully. As an example of saving networks, we visualize an implemented scenario of two small community networks in two regions of Bangladesh *A Collection Of Community Architects' Work Across Asia - 2016* (2016), i.e., Jhenaidah city and Dinajpur city. Note that this approach can also be extended to any other rural in developing countries.

In this scenario, five low-income communities with around 160 families of Jhenaidah city, located in the south-west of Bangladesh, formed a network to upgrade their living environments. They used to save a small amount of money every week. With their savings and small loans from outside, they have been building their houses.

Seeing the success of Jhenaidah community networks, low-income communities of Dinajpur city, located in the north-west of Bangladesh, has started saving networks to obtain the essential knowledge to improve their living environments too. Initially, they started to visit Jhenaidah city physically to learn the knowledge behind this success. This kind of physical visit is expensive for them. Here, *AsthaNet* can help to store the knowledge digitally and share them among communities. This can reduce the time, cost and visit as well as help faster spreading of the community development progress. Jhenaidah community networks have already been acquiring a revolving fund by themselves, which continues to increase year by year. If Dinajpur community networks are connected to Jhenaidah community networks with the help of *AsthaNet*, that yields a larger amount of money not only to Dinajpur community networks but also to Jhenaidah community networks. From this property, we expect that thousands of low-income communities can join together and form a nation-wide network. When a new community network newly joins *AsthaNet*, people in the community can learn from the success stories of other communities that have already joined *AsthaNet* as illustrated in Fig. 10. *AsthaNet* will open-up at least the following opportunities for the community with saving networks: a) It will enhance the transparency of the savings process by creating the opportunity to see the amount of savings regularly. b) After each transaction, people know the details of the community savings and percentage of their participations. This transparency of the saving process will give the community's people confidence of adding their savings to do something big.

4.2.2 Housing Network

In developing countries, people are deprived of their basic housing needs, where the shelter is one of the basic human needs. Most of them are building their houses in a self-help

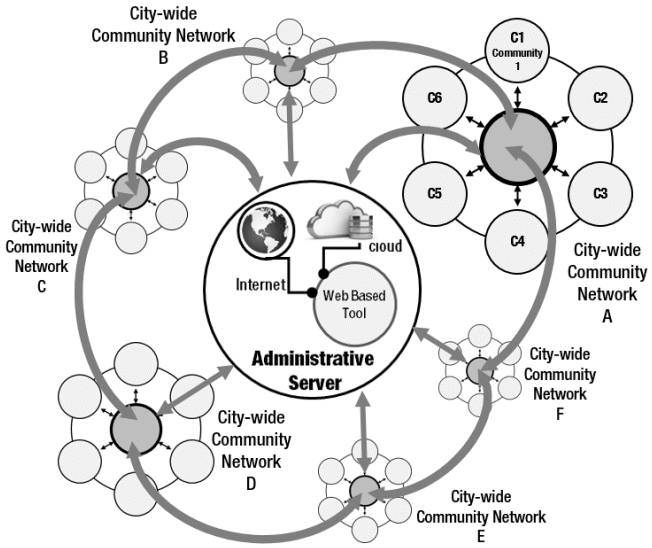

Figure 10 Rural community-wide, City-wide and Nation-wide Saving and Housing network through *AsthaNet* to empower rural communities by Savings and by Housing concept, such as innovative architectural designs, constructions, skill sharing and developing, and resource sharing.

basis by their individual family effort. Lack of knowledge regarding safety, cost-effective technologies, efficient land and space use and ecological and cultural sensitivity is leading to poor living environments. Sometimes, people need not to invent the solution because it has already been established in other neighboring community. What we need is only connecting the communities to *AsthaNet*. For example, people in coastal areas of Bangladesh know how to build stronger roofs resilient to cyclone, people in the hilly areas know how to build stronger houses with bamboos, whereas people in the north of Bangladesh know how to build better houses with mud *A Collection Of Community Architects' Work Across Asia - 2016* (2016). Architects and engineers are also doing research on how to build cost-effective, stronger, environment-friendly, culture sensitive and beautiful houses. When we can create an opportunity to connect all these groups through a trustworthy network like *AsthaNet*, there is a bigger possibility to make the living environment better with the existing shared resources. People may not be able to afford this network individually. However, it can be affordable by organized co-operatives. *AsthaNet* also offers to organize these community networks faster and better as illustrated in Fig. 10.

4.3 Agriculture Sector

Rural agriculture sector of third world countries often experiences unexpected loss and reduced production, due to lack of modern farming knowledge and proper awareness. Appropriate utilization of ICT technology facilitates many opportunities to change the scenario there.

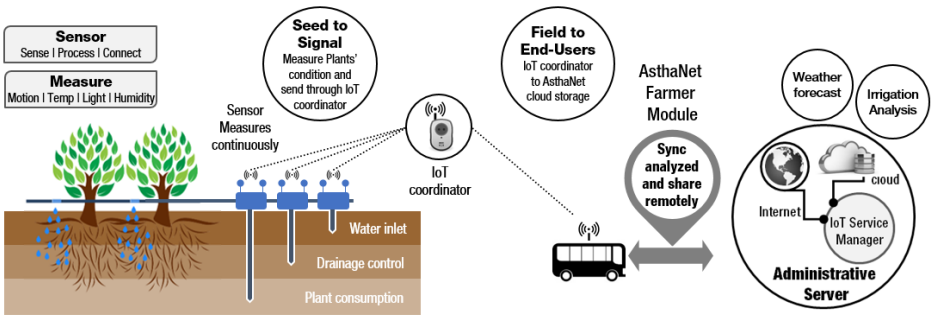

Figure 11 Precision agriculture through distributed IoT-devices in *AsthaNet*.

4.3.1 Serving Agricultural Queries on Demand

In *AsthaNet*, the farmers exploits *Customized-Query Service* to obtain an appropriate solution for a specific problem related to their agriculture, poultry, fisheries, etc. It is important to appropriately prepare localized information contents for this purpose.

4.3.2 Promoting Awareness

Rural farmers should learn modern farming and preventive measures to avoid farming threats, e.g., pests, drought and flood. General information data service and farmer module (*Service Module*) encourage the promotion of organic vegetable and quality food, which is grown without poisonous pesticides. Instructive short films and info-graphics are cached at *Local Agriculture Data Center* and shared among farmers, free of cost. Besides, the technically less sound farmers are able to ensure the quicker response to their specific query through *Guided-Query Service* and many related CDN contents cached at *Local Agriculture Data Center*.

4.3.3 Remote Treatment of Livestock

Providing remote treatment of livestock is one of the implementable applications in *AsthaNet*. In rural communities, a veterinary assistant can be remotely achieved by primary diagnostic digital tools, which act as IoT devices, and customized *UserApp*, and thus rural farmers can remotely obtain a respective service from veterinary hospital/experts at the urban.

4.3.4 Precision Agriculture in Disconnected Communities

Analysis of local weather condition and sensing data related to crop's present condition, which are collected from the agricultural fields, can lead to accurate and efficient guidance. Thus it could greatly influence the better cultivation procedure for disconnected farmers.

Deployment of necessary and relatively low price sensors (IoT devices) in crop fields brings better cultivation known as precision agriculture. Deployed sensors the farm condition, e.g., measure soil moisture, temperature, humidity and light proximity, and then these sensed data are propagated to *Iot Coordinator*. *Local Agriculture Data Center* and *Movable Server* allow *IoT Coordinators* to synchronize those at the *AsthaNet Cloud Storage* of *Administrative Server*. Sensed data become available at the respective IoT solution provider through the *AsthaNet Web-based-Tool* and then get processed. The decided

response/actions become available at receptive *IoT Coordinator* through the *AsthaNet* platform. The appropriate actions are also triggered accordingly by *IoT Coordinator* itself. Fig. 11 illustrates this concept for *AsthaNet*.

4.4 Education Sector

Proper education is one of the most crucial factors which causes dramatical change in socio-economic condition of any nation. To keep pace with the ever-changing world and their educational facilities, the access to global repository, e.g., the Internet, is a must. *AsthaNet* can promote education facilities in deprived and disconnected rural students.

4.4.1 Distance Learning and Off-line Access to Digital Library

Educational resources in both standard and localized formats are prepared at *Administrative Server* and then delivered, free of cost, through *Guided Query Service* and general information data service to facilitate distance learning. Gradual collections of such resources enrich the resource pool at *Administrative Server* and all *Local School Data Centers*. Local resources, e.g., lecture material prepared by local expert personnel, are also preserved at different *Local School Data Centers* to further enrich the resource pool. All text books of different writers on different topics are also available in *Administrative Server* and *Local School Data Centers*. Thus, these are available to *End Users* in an on-demand fashion through *Guided-Query Service* and do not need interaction with *Administrative Server*. Rural students are not able to use Google customize search or education tools like Khan Academy*Wikipedia* (2017). *Customized-Query Service* can allow them to have access on those with minimal cost.

The admission application forms for college or university are offered through value-added *Student Module* which allows off-line access to the college/university websites. *Customized-Query Service* also extends this service for the disconnected rural students.

4.5 Serving Rural Women

Through the *AsthaNet* platform, the level of women employment in remote rural communities can be improved by setting policies for the women specially. For example, giving them free training to be qualified for carrying *Local Server* or to be ICT entrepreneurs of Social Business if necessary hardware requirement are available.

Both the general information data service and *Service Modules* take an effective role in promoting and strengthening rural women folk. In this context, *AsthaNet* provides appropriate localized audio visual contents, free of cost, through general information data service and *Service Module*. These educational documentaries raise consciousness among them in the following major areas, e.g., health, childcare, sanitation, cleanliness, proper cooking methods, handicrafts, making pickles and similar other activities. Moreover, *Customized-Query Service* well serves these deprived women by constructively responding to their explicit queries. Thus the *AsthaNet* platform gradually alleviate their concern ignorance. Moreover, for technically sound rural women, the CDN contents cached at *Local Entertainment Data Center* ensures *Guided Query Service* for quicker response and can serve frequently asked and urgent information.

4.6 Business and Commerce Sector

Accessibility to up-to-date information regarding business products can greatly maximize scopes and prospects of rural producers and businessmen.

4.6.1 Virtual Market

Establishment of a virtual market facilitates an effective platform for rural businessmen in marketing their products. Quick and efficient product advertisement and justified product price are achieved through this virtual market. Unconnected businessmen can avoid cheat with the information of current price in neighboring rural communities or cities.

The implementation of virtual market requires to collect product prices and their availability from different rural businessmen to respective *Local Business Data Center*. A summarized report is then prepared at *Administrative Server* which also includes prices in city areas. This report is then delivered again to the remote businessmen through *Local Business Data Center* to be displayed locally. These advertisements and transactions do not need to be processed in a real time manner. Hence, the *AsthaNet* concept is absolutely appropriate here.

4.6.2 Optimizing Business Purpose Transportation

Availability of product information at different *Local Server at Business centers* of remote rural communities allows *Administrative Server* to prepare a business purpose transportation strategy. *Administrative Server* requires the maps of nearby rural communities, from which the distances between rural communities are calculated Hence, rural vendors select the nearest destination to ship their products with a hope of having higher profit.

4.7 Life Style and Ethics

AsthaNet has a significant influence on improving rural life-style. People living there can learn many social and ethical values which gradually shape their views. Thus, *AsthaNet* can be a milestone for building a peaceful society there. Proper utilization of customized *UserApp*, different *AsthaNet* Services Modules and different *Local Data Centers* meet these goals.

4.7.1 Promoting Etiquette in Youth

AsthaNet contributes to boosting up social ethics and spiritual values among rural youth. Documentaries on social and spiritual etiquette are projected at *Local Entertainment Data Center* and/or are provided to the rural youth through *Student Module*. These resources are developed in localized languages and *Local Entertainment Data Centers* preserves those as CDN contents.

A great deal of training can be conducted through Business module, with sufficient information contents and local expert personnel. Such training can be in various fields, e.g., electronics, solar home systems, mobile phone repair, fisheries, looms, carpentry, breeding cows and goats, milk production, growing seedlings, tailoring, potteries, small scale businesses development and others depending on the demands.

4.7.2 Enlarging Employment Opportunities

The *AsthaNet* platform creates significant demands for the quality operators, quality content developers, analytics, quality assurance and programming-related tasks. These benefits significantly give new job opportunities to people in the community.

AsthaNet also plays a vital role in extending many more employment opportunities among rural youth communities. *Customized-Query Service* allows them to get access to the information pool related to job opportunities at the urban. Moreover, on-line job application process can be accomplished through *Customized-Query Service*.

4.7.3 Off-line Community Network

Availability of sound communication facilities within local rural communities has a great impact on promoting socio-economic condition as well as social life style. *AsthaNet* prominently ensures these facilities within infrastructure-less disconnected rural communities.

Local Messaging Service (LMS) allows disconnected *End Users* to exchange their messages among themselves. The detail of this functionality is already discussed in Section 3.10. Moreover, *Customized-Query Service* even enables such communications among other community's people or inter community communication through *Administrative Server*. Thus, the cost of the Internet or traditional connectivity are bypassed by rural community people.

In today's virtual world, people are digitally socialized each other via different social networks like Facebook, Twitter and LinkedIn. However, for remote rural communities without Internet infrastructure, these facilities are hard to achieve. *AsthaNet* unlocks the networking possibility in these scenarios, where the *AsthaNet* platform ensures non real-time access to such features there. Comments, pictures and videos are shared here, not instantly, but with a delay. Similarly, e-mails can also be shared. *Movable Server* carries the updates and puts those on *Local Entertainment Data Center* or *Local Servers* for ultimate synchronization at concerned *End Users*.

4.7.4 Information Dissemination

National important news, events associated with local communities, national and regional vaccination days are disseminated among disconnected *End Users* through the general information data service, free of cost.

4.7.5 Remote Access in Bus Terminal

Inter district bus tickets can be even booked in advance by disconnected *End Users* through *Customized-Query Service* or off-line access to service providers website.

4.8 Fishermen and Boatmen Communities and Communities on Islands and Mountain Areas

Access to forecasted weather condition information is a crucial need especially for fishermen and boatmen at sea and coastal areas. Because of the intermittent network, there is no other choice to get the instant messaging service.

Besides, the conventional network is not possible in communities on hilly mountain areas or in communities on islands, e.g., islands in Maldives, Indonesia, Comoros, Fiji

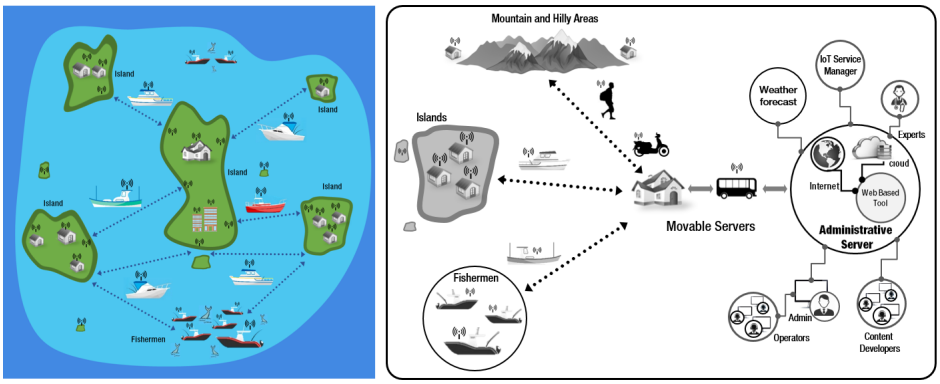

Figure 12 Connecting disconnected islands and fishermen communities using *AsthaNet*.

and Philippines. Fig. 12 illustrates the connecting disconnected islands and fishermen communities using *AsthaNet*.

In these kinds of infrastructure-less scenarios, the *AsthaNet* platform offers a better alternative, where local server and/or *Movable Server* on speed boats or other movable vehicles serve the updated information, e.g., weather forecast to the individual boatman/fishermen, rural community in coastal area/islands or hilly areas.

4.9 IoT in Disconnected Rural Community

AsthaNet's cloud-storage provides a robust web-based platform for IoT solution providers to introduce IoT at disconnected rural community where the instant decision processing is not essential. Different IoT devices with the coordination of *AsthaNet* platform are implemented in remote infrastructure-less disconnected area. Animal mobility monitoring and cattle management are also a promising application which is feasible to implement through our platform.

AsthaNet provides a trusted network platform among wireless connectivity enabled any device of IoT system in the rural disconnected areas, which is a remarkable feature to attract the IoT service providers. This platform follows a ubiquitous approach to sense, monitor, manage and control the surrounding environments of rural communities.

4.10 AsthaNet as Social Business

AsthaNet is considered as a social businesses by strategically monetizing it and ensuring the financial focus into revenues with social mission. Within this social mission ecosystem, the social entrepreneurs act to not only serve the customer needs (of updated localized information content) and creating wealth, but also enable profit generation. This presents a for-profit social business by ensuring the financial sustainability of the network architecture. The profit generated is aimed to be re-invested into the mission.

4.11 Knowledge based network for the community

Asthanet creates a knowledge society that generates and disseminates knowledge to all members of a society, which are utilized to enhance their socio-economic development.

Unlike an information society, which only generates and spreads the raw data, a knowledge society serves to transform information into actionable insights that allow members of the community to take effective measures for the their betterment Castelfranchi (2007). AsthaNet provides a knowledge based community network platform using modern communication technology for sharing of data resources and create an efficient knowledge society.

4.11.1 Mapping Network

Mapping Network are established to map and connect different communities across a region for sharing of valuable knowledge. Each community may hold distinct and unique knowledge of solving specific problems; these are useful for other communities as well.

4.11.2 Energy Network

Energy Network are used to monitor homes and communities with distinct sources of energy resources for electricity and cooking. This data could then be utilized to spread awareness on the efficient and clean usage of energy resources across other communities.

4.11.3 Green Network

Green Network are setup to map nurseries, parks, gardens and green fields across a community. People with access to this information can look for the closest green resource that they need.

4.11.4 Pond Network

Pond Network are utilized to connect ponds across a community to share valuable knowledge and experiences on water-body cleanliness and fishery.

4.11.5 Kid-Play Network

Kid-Play Network is used to connect playgrounds across a community, that will aid children across a community to seek closest desired playing grounds.

4.11.6 Student Network

Student Network are established to connect libraries and education centres across a community. Information on education facilities and available books are shared across the institutions.

5 CONCLUSION

This is a proposal intended for the complete plan of making a rural community autonomous in terms of communication, data transfer and knowledge sharing. With the practical implementation of this *AsthaNet* platform successfully, a perfect network through which infrastructure-less and disconnected local rural remote communities transfer data, connect within themselves and use the concept in daily aspects in an efficient way.

This is a kind of empowerment which is neither top-down nor bottom-up – it is horizontal – a development with dignity. *AsthaNet* platform aims to exploit the market gap that exists at the intersection of the demand of five stakeholders, namely: i) Infrastructure-less disconnected rural community, ii) People of all jobs sectors and all ages eager to get information, iii) Technically unsound *End Users*, iv) Quality content developers, and V) Rural community ICT based social entrepreneurs.

The launch of the *AsthaNet* platform is not the end of process, it's the beginning. *AsthaNet* co-creates and re-invents the ways for the rural *End Users*, local content developers and local social entrepreneurs to create, share and enjoy quality localized data contents with localized dialects and accents. These disseminated knowledge are then utilized by members of societies to take action for addressing their surrounding social issues. By attracting stakeholders from different segments, and with the help of state-of-the-art technology of message ferry assisted DTN, TCP/IP, CDN, IoT devices, etc., *AsthaNet* is aiming to achieve its goal - "To co-create an innovative, informative and trusted network solution for connecting the disconnected communities and initiate knowledge societies".

Note

[1]In Bangla language, Astha (origin from Sanskrit) means trustworthy, faithful, confidence on something. As for the justification, Astha Network (*AsthaNet*) provides a trustworthy communication solution where rural communities build a faithful network among themselves.

[2]Ants interact using their antennae on their heads when they meet another ant using pheromones (chemical signals), sounds, and touch. They exchange and share information to know about their identities, food availability, colony ID, assigned and designated tasks, etc.

[3]Wi-Fi Direct or Wi-Fi P2P enables a device to easily connect with one or more devices simultaneously for file transferring at typical Wi-Fi speeds without using a wireless access point (WAP). It connects devices from different manufacturers and establish a peer-to-peer connection with less technical setup.

[4]A call center is used for receiving or transmitting a large volume of requests by telephone that offers services like phone answering, email response, live chat, telemarketing, and social media customer support. A call center has work stations that include a computer for each agent, a telephone set/headset connected to a telecom switch, and one or more supervisor stations.

[5] A query where restrictions on query representation formats are weakly defined.

[6]A table describing information content category detail which are used for quick information retrieval from a large pool of information content.

[7]CDN Service Module is fully compatible with any further additional categories and adoptable with network scalability.

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