# Social Life Networks for Middle of the Pyramid

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**ABSTRACT**

We are living in an age of social media that provides numerous channels for digital expression and sharing with people almost instantaneously in any part of the world. By bringing different media as well as modes of distribution -- focused, narrowcast, and broadcast -- social networks (SN) have revolutionized communication among people. We believe that by using the enormous reach of mobile phones equipped with myriads of sensors, the next generation of social networks can be designed not only to connect people with other people, but to connect people with other people and essential life resources. We call these networks Social Life Networks (SLN) and believe that this is the right time to focus efforts to discover and develop technology and infrastructure to design and build these networks.

## 1. INTRODUCTION

In the last decade, management thinkers and economists have popularized the term: Bottom of the Pyramid. Prahalad [1] compellingly argued that we should stop thinking of the poor as victims and instead start seeing them as value-demanding consumers. According to him, there are tremendous benefits to multi-national companies who choose to serve these markets in ways responsive to their needs. Bottom of the Pyramid (or BOP) has attracted significant attention from many communities including businesses, governments, and economists in the last decade. That perspective was motivated by the needs of multi-nationals and politicians. We adopt a technology driven perspective to the developments in the last few decades and propose approaches that have potential to make difference in most parts of the world.

The world population can be classified in three distinct classes (see Figure 1): the top layer of the pyramid (about 1.5 Billion) have access to modern Networks using their smart phones; at the bottom of the pyramid (about 2 Billion) are the people deprived of any modern means of communication. At the Middle of the Pyramid-- we will call them MOP in this paper--, are about 3 Billion people who have mobile phones but are not part of the modern Internet. The middle has been growing and is now about *half of the world's population*. Development of appropriate technology to enable the mobile phones commonly used by MOP to become part of the next generation Networks, has positive implications from technology, business, as well as humanitarian perspectives. By employing emerging sensor networks combined with participatory sensing by MOP, we can harness collective knowledge of society to develop Social Life Network (SLN) for analyzing emerging situations and connecting people to appropriate resources for better utilization of resources in normal as well as emergency scenarios.

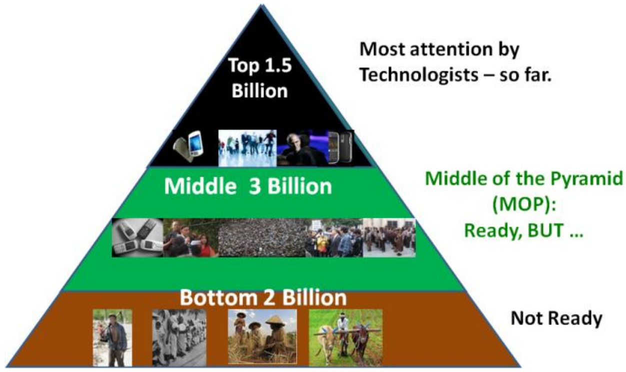


**Figure 1: Mobile phones and Internet have created three clear layers in global population. The top layer has access to both Mobiles and Internet, the middle layer has access to Mobile, but not Internet, and the bottom layer has access to neither.**

We believe that the technology development for MOP is very attractive because it has potential to impact on the life of more than half of the underserved population of the world. Moreover, the technology is ready to address the challenge and sociological factors suggest that our society in not only ready but is supportive.

This paper is in part a vision paper; but it also proposes technical architecture, and discusses some research ideas and results as a step towards realizing this vision. We believe that implementation of SLN requires progress in many different technology areas related to computer science and human-computer- interfaces. Our description here is more to start discussion based on some experience rather than a proposal for a complete system.

## 2. NEXT GENERATION SOCIAL NETWORKS

One of the most popular and impactful concept in the last decade has been Social Networks (SN) built using modern information technology. Undoubtedly, social networks have been popular since the beginning of civilization and have played a significant role in the development of human society. Basically, in a social network each person could be considered a node that has connections of various kinds with different individuals. The connections could be of many different kinds ranging from family relations, friendships, business relations, religious relations, sexual relations, hobbies, and numerous other types. Social scientists have studied such networks for long time. With progress in Internet related technologies, in the last decade the nature and impact of SN resulted in transformative effects on society. Several major political events in the last 3 years, such as revolutions in Iran, Tunisia, and Egypt, are directly attributed to use of emerging SN technology.

Boyd and Elison [2] define SN sites as:

*"We define social network sites as web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system. The nature and nomenclature of these connections may vary from site to site."*

These computer mediated sites have brought in many novel practices. Not all of the new practices are universally accepted, but their impact and popularity has clearly demonstrated the power of almost instantaneous multimedia communication among people independent of the distances among them. Another very important feature of these networks is their ability to combine one-to-one, one-to-group, and broadcast modes using multimedia within the same framework effortlessly. A very good history of the evolution of SN is given in [2].

A SN provides each member an ability to create their profile and select people who they want to be connected to. In a network sense, each person is a node and selects his/her connections. In most SN, the connections are symmetric meaning that if X is connected to Y then Y is connected to X. In some networks, like Twitter, these relations are not symmetric so X may follow Y, but Y may not follow X. Another important dimension in social networking is what a user does to communicate with others and what kind of information he can receive. A very common mechanism for people to communicate in SN environment is to provide some kind of micro-blog, like a tweet in twitter or a status update in Facebook. Increasingly these micro-blogs are going in the direction of photos and videos. A major transformation in SN is taking place due to increasing use of mobile phones, particularly so-called smart phones, as the client in these networks. It is now much easier to send your location information or a photo from where you are than typing a status updates. Last few months have seen tremendous growth in companies that allow user to share their current location using check-in (e.g. Foursquare, Gowalla, SCVNGR), or send a photo with some light-weight image processing (e.g. Twitpic, Path, Instagr.am, PicPlz). These services also allow short captions or status updates. Obviously, the popularity of check-in and other location based services is due to popularity of GPS in phones. Similarly, rapid advances in camera technology and availability of data bandwidth and storage for mobile phones are resulting in rapid increase of visual communication through photos.

Check-in and photo based micro-blogs are indicators of a novel trend that is likely to become very popular soon. These trends indicate that people use sensors in a device to provide updates about where they are and what they are experiencing. This trend of sensor based 'status updates' are currently mostly initiated by a person every time, but are soon likely to become more automated based on pre-specified conditions. It is believed [30] that healthcare may be revolutionized using such sensor based status updates based on an individual's health parameters.

Current SNs are designed with the primary goal of facilitating communications among people using emerging technology. These networks provide us tools for focused, group-based, and broadcast mechanisms to share our experiences and opinions using a plethora of emerging multimodal mechanisms. In a sense, one could consider that the last few years have seen transformation in approaches to creation, storage, distribution, and sharing of experiences using technology that emerged in the last few decades. This definitely has a long term sociological implications as articulated so well by many new media thinkers such as Shirky [4]. It is common to relate the effects of these mechanisms like Twitter and Facebook to several revolutions, such as the one that we just witnessed in Egypt and many social changes systems like Ushahidi [9] are bringing in developing world. The most important feature of these systems is the ability for people to spontaneously and instantaneously communicate with appropriate people, or groups, using multimedia.

The next generation networks are likely to build on successes of SN and technological advances made in the last decade. These networks will include different types of resources in the network as their integral components just as the current generation does for people. The resources could be material resources, services, and other people who play the role of service providers. To accomplish this, the *sensor networks* and *Internet of things* will become parts of these networks. We call these next generation networks Social Life Networks (SLN). *These SLN are not only for communication among people for sharing experiences, but are also for helping people connect to resources that are required by them*. Like current SN, SLN should do this with least latency possible and should allow this to happen effortlessly for people. By connecting people to resources these network will become important part of many essential activities in regular day to day life activities of people.

There is a clear trend for people to increasingly use their mobile phones for participating in SNs. If technology could be developed for allowing 'feature phones' to be used as a client in SLNs, then we could bring the advantages of connecting MOP people to resources effectively and this will help solve many problems in emerging countries. Effectively, it is now within the reach of the technology to bring advantages of information and communication revolution to help the MOP. We believe that time is right to start implementing such networks. In this paper, we discuss technical aspects of what we believe are some important components to implement the first version of SLN to understand challenges and required essential functionality to bring these concepts to MOP people.

## 3. SOCIAL LIFE NETWORKS

Figure 2 shows high level functional architecture of a SN. The basic functionality of these networks is to allow people post their multimodal experiences in the forms of micro-blogs using text or multimedia and specify any other information, such as their location or activity they are participating using some variant of check-in functionality.

Mobile phones now have many sensors to automatically capture activity and other status related information about people unobtrusively. These phones also have ability to easily capture audio-visual experiences and observations and post those easily, often requiring lesser effort than typing 140 characters, for sharing those with either a limited group (as commonly done on Facebook), and broadcasting them for everybody (as is typically the case on Twitter). Many research efforts [10, 11, 12, 13, 14] show that by aggregating such micro-blogs one can find useful information related to evolving situations.

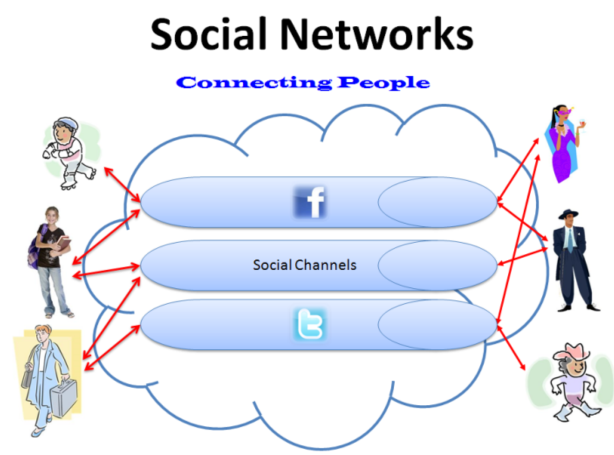


**Figure 2: High level view of current social networks**

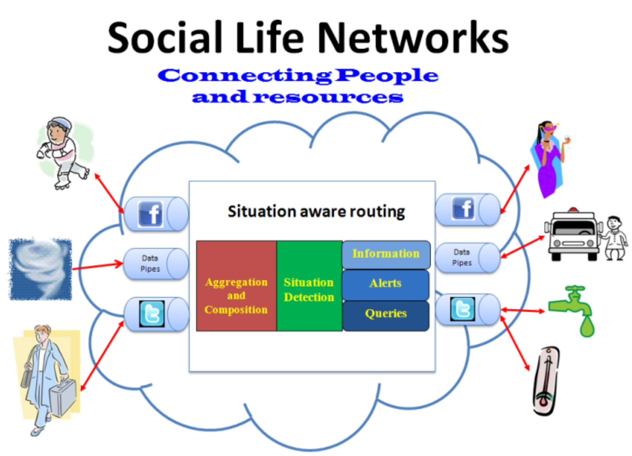


**Figure 3: High level view of imminent social life networks**

Now suppose that one extends the concept of tweets to all sensors. Each sensor is placed where some event of interest must be detected. If we design sensors (with processing either on-board or where the sensor sends measurements) so that they broadcast as soon as an event of interest occurs, then we can assume that each sensor will broadcast the event it detects. Now, let us define *tweeting* as simply the *act of broadcasting one's status*, which can be done by any device or human. Thus, in the following tweets are not related to a specific company, but are considered a general process. In other words, in the above discussion we consider that *each sensor starts tweeting*. In many cases, these tweeting sensors may be on a moving vehicle (tweeting arrival in pre-specified area or position at predetermined intervals), in a mobile phone, or at pre-specified locations. Such sensors may also be put at different types of service stations, or just at different locations, to determine specific physical attributes (number of people passing, temperature, wind velocity, rainfall, …) and tweet that information.

Thus we will have an environment in which people will be communicating their status and their needs and different sensors will be tweeting about the physical measurements at different locations of interest as well as the observations that could help in determining utilization status of resources. By processing this micro-blog and micro-event information, one could determine situations and status of different kinds ranging from evolving emergency situations, to routine situation about position of a bus relative to a user's position, or lines at a doctor's clinic in the area. It will also be possible to develop algorithms to advise a user to take appropriate actions based on her own situation and the system's knowledge of appropriate resource status within reach.

Figure 3 shows high level architecture of such a SLN. As shown here, the main difference in these systems compared to current SN is that the system is continuously monitoring situations and based on the input and requests received from a user, it connects them to appropriate resources.

As is well known, in developing countries, due to infrastructure limitations and the *scarcity of information* about it, essential life resources like healthcare, transportation, water, and agricultural resources, are much less accessible than they are in the developed world. SLN infrastructure will start by building on the mobile phones and other inexpensive sensors that are already starting to appear in many devices and build the infrastructure and framework to access and utilize different services in daily life for the next 3 Billion people in the world. In the following, we present some research that is relevant to building these systems.

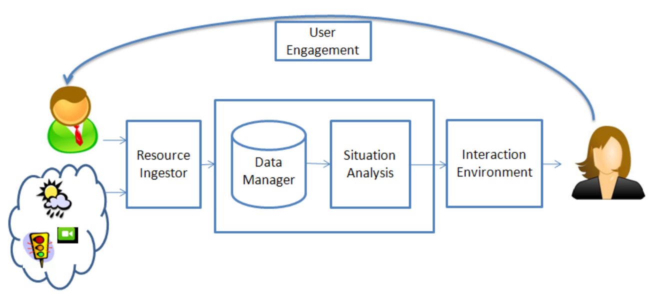


**Figure 4: Essential components for realizing social life networks**

As shown in Figure 4, we need a few basic components for realizing the vision of social life networks. Data coming from multiple users and heterogeneous devices needs to be wrapped into a common format and made accessible to the system. Multiple issues of scale, real-time processing and indexing need to be handled for the physical organization of data. Logically the data needs to be translated from localized sensor/human input to higher level situational abstractions. Based on the situation detected the users will be connected to the appropriate human or device resource. This connection needs to be done by an interaction environment cognizant of user needs and MOP background. Finally, there is an encompassing issue of user engagement. Both intrinsic and extrinsic factors matter, but enhanced feedback and user motivation are key aspects of it.

## 4. FINDING AND MANAGING RESOURCES

In order to effectively connect people to their desired resources and people, it is critical for a SLN to own a resource manager that collects and manages related data from sensor networks. In this section, we categorize the potential data sources for building a SLN. In addition, we propose the system architecture towards such a resource manager.

### 4.1 Discover Data Sources

Varieties of sensors are available to capture useful sensory data about human life. We categorize these sensors into two large classes, i.e. physical sensors and human sensors.

Physical sensors, such as cameras, microphones, and motion sensors, refer to the sensors that are purposely set up in a location by human to observe events and objects at that place. For example, cameras are commonly used to monitor events or changes in objects. The sensory data generated from the physical sensors can be in many different formats, e.g. image, video and audio. The raw multimedia data usually needs to be processed to produce enough knowledge for human being to understand. On the other hand humans, with the intrinsic intelligent sensory system inside our body, are naturally good at sensing the world around and creating knowledge out of it. The output from the human sensing and knowledge creation process can be documented in various representation formats, e.g. writings, paintings, music, and movies. Among these formats, text (or written language) is the easy and commonly used approach to communicate ideas between people. Moreover, the tremendous development of World Wide Web in the past decade has greatly pushed forward the growth of textual interlinked data, in the form of web pages, blogs, and micro-blogs, etc. Consequently, the management of such textual data has been received well in the research community.

Given the two types of sensors and the differences in availability and quality of the sensory data, we identify three major data sources:

1. Textual documents on the Web;
2. Real-time micro-blogs on the Web;
3. Other sensors, e.g. traffic cams, humidity detectors.

### 4.2 Architecture of Resource Manager

To make full use of the sensory data, we should build an information system that ingests and manages the sensory data, and allows efficient access from end users. An architecture is shown in Figure 5. The following components need to be designed and implemented in the system:

1. Well-designed object and event model for modeling and structuring data from real world;
2. Robust storage system for storing the object and event data;
3. Efficient indexing mechanism supporting fast access of object and event data to ordinary users;
4. Flexible data ingestors that can integrate and transform raw sensory data into the system.

#### *4.2.1 Object and Event Model*

Object and event models are essential for the resource manager to represent information extracted from raw sensory data. Works on object-oriented paradigms have resulted in a modeling approach for object, which encapsulates common attributes and methods about a class of objects in the model. We conducted studies on event modeling, and proposed a six facets model [18] that captures the fundamental aspects of event, including temporal, spatial, informational, experiential, structural and causal facets. Time, location, information and experience are introduced for characterizing each individual event, while the structural and causal aspects capture more about the inter-relationships between events.

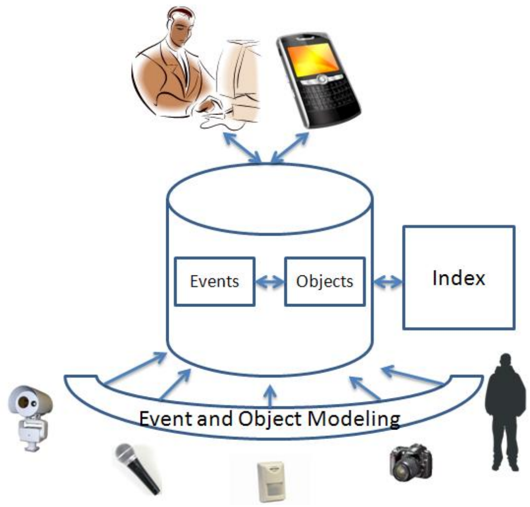


**Figure 5: Architecture of Resource Manager in SLN**

### *4.2.2 Flexible Data Ingestor*

As discussed above, three types of data sources are currently suitable for gathering events and related objects. To encompass these data sources, pull, push-based, as well as newer filtering of broadcasted data stream based collection mechanisms have to be considered.

1. For the textual documents on the Web, crawlers and information extractors should be designed and implemented for us to collect and select relevant information;
2. For the real-time micro-blogs, stream *filtering* (on broadcasted data streams) is the proper approach to access the data. Processing techniques in streaming mode, such as new event detection, and topic detection and tracking can be applied to detect and combine related data.
   For other sensors, depending on the quality and rate of the data, push or pull-based approach is selected.

### *4.2.3 Storage and Indexing*

Once objects and events are collected and extracted from the sensory data, these objects and events are required to be appropriately stored and indexed to allow efficient queries from users. For the storage system, it should be able to handle large volume of streaming data. For the indexing mechanism, temporal, spatial and spatio-temporal indices are particularly important for users to find relevant resources in SLN[28, 29]. Index on other alpha-numeric data types, should also be supported so as to enable queries on information and experiential aspects.

## 5. SITUATION AWARENESS

As shown in Figure 3 earlier, one of the fundamental building blocks of Social Life Networks will be the connection between people and resources based on the *situation* at hand. For example in a health care (swine flu monitoring) application, the system will be able to give different recommendations to different users tweeting about flu-like-symptoms (*e.g. 'arrrrgh ! got a sore throat'*), based on their personal inputs as well as the *situation* in their surrounding geo-location based on factors like number of similar incidents reported, growth rate, population density and so on.

While there is general consensus on the importance of *situations* in such scenarios, the term situation is 'loaded' and interpreted very differently across different fields and application contexts. We are building approaches to computationally define '*situations'* in social life network context, as well as tools to characterize and detect it.

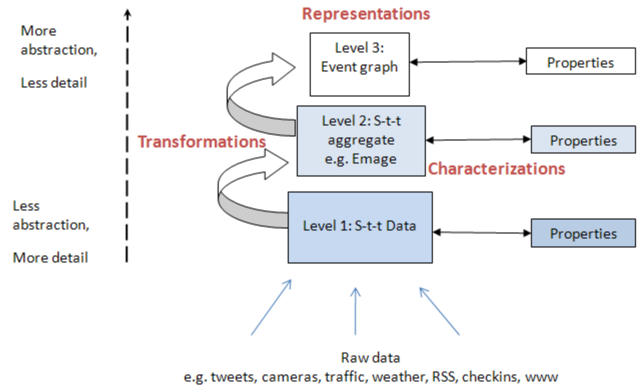


**Figure 6: Proposed framework for situation analysis**

Our basic premise (see Figure 6) is to combine heterogeneous data coming from all types of human and device sensors into a common spatio-temporal-thematic representation.

This common data model can be represented at different levels of abstractions (e.g. ranging from individual spatio-temporal-thematic data nuggets, to aggregated event graph), with characterization possible at each of those abstraction levels. Combination of these representations and characterizations can be used for human level visualization, querying, as well as assisted decision making.

We computationally define situation as "*an actionable abstraction of observed spatio-temporal descriptors*", and are currently defining a framework which allows human level experts to model situations of interest in the application domain as predicates on the mid to lower level spatio-temporal features which can automatically be extracted from the data available. Thus the idea is to *bridge the semantic gap* between the higher level actionable abstractions based on which humans reason about decisions and lower level features which can be directly computed by a machine.

While two of the levels shown in Figure 6. (spatio-temporal-thematic data and event graphs) are employed by other works too (e.g. [13], [15]), we have defined an intermediate level spatio-temporal-thematic aggregation which we call *Emage* (an event driven analog of *images*).

This computational metaphor is based on the following analogy. Traditional imaging sensors use pixels that represent aggregation of photon energies striking in the pixel area on the sensor. We define *social pixels* as aggregates of different user contributions coming from a particular geo-location. For example, a large number of tweets about 'swine flu' coming from a particular geo-location can be represented as a 'high' value at the corresponding pixel.

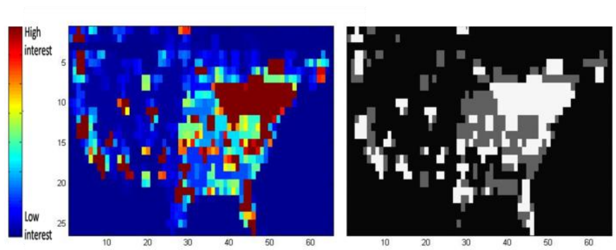


**Figure 7: (a) A 'social image' representation of the `swine-flu' interest data across US. (b) Segmentation of image into 3 regions of different activity level.**

The abstraction of social media content into spatio-temporal 'pixels', 'images', and 'videos' has implications on multiple aspects.

- **Visualization:** This approach allows for intuitive visualization and hence aids situation awareness for a human user.
- **Intuitive query and mental model:** The correspondence of the human mental model of spatio-temporal data with the query processing model makes it easier for humans to pose queries, and understand the results.
- **Common representation:** This representation allows multiple spatio-temporal data sources (e.g., maps, weather info, demographics, geo-coded twitter feeds, Flickr images) to be assimilated within the same framework. This representation is independent of the nature of the original source; it extracts information from multiple sources and collects them in one application-centric representation.
- **Data Analysis:** This representation allows us to exploit a rich repository of media processing algorithms that can be used to obtain relevant situational information from this data. For example, well-developed processing techniques (e.g., filtering, convolution, background subtraction) exist for obtaining relevant data characteristics in real time. Such analysis would be very tedious in a text-based corpus of similar data or even as query-based approach in traditional databases where (relatively simple) media processing operators like convolution and segmentation are yet to be mapped effectively.

Besides these, a spatio-temporal binning is better for individual user privacy, and reduces run-time query processing cost.

We realize that end users of such systems are unlikely to be experts in the procedural aspects of data processing. In fact, procedural method and languages are known to require significant training before users can employ them, and often tend to be tool and format dependent [16]. Hence, we have started work [17] to define a set of declarative query operators on e-mages (event based analog to images), where the user just describes her data needs. The defined spatio-temporal query operators allow users from multiple domains to interact with the social media data and ask questions on derived attributes (e.g., velocity, epicenter of the distribution) which would not be available directly out of raw data feeds We have defined 6 basic sets of operations viz. *Selection, Arithmetic and Logical Aggregation, Grouping, Characterization, and Pattern matching*, for analyzing any spatiotemporal data. The *Selection* operator specifies the spatio-temporal bounding box to perform the other operations. The *Arithmetic and Logical operators* allow combination and comparisons across multiple e-mages (e.g. add, and, multiply, convolution). The *Aggregation* operator allows temporally related e-mages to be combined into a single e-mage. The *Grouping* operator splits an e-mage into multiple e-mages corresponding to different *segments* representing semantic entities (e.g. see Figure 7). The *characterization* operator represents different attributes (e.g., epicenter, density, shape) for each of the segments. Lastly, the *pattern matching* operators can be used to see how closely the captured phenomena match known patterns or related historical data.

Our early works [12, 17] have demonstrated applicability of this approach for applications like swine flu monitoring, business decision making, political event analysis, and seasonal characteristic detection.

## 6. Interaction environment

The first generation computing environments were developed for scientists and required extensive training to use. The second generation computing entered more main stream applications in developed countries and was used in business, education, health care, entertainment, and other domains. Developers refined interaction environments so educated novices could use them without much training. Experiential Interaction environments [19] are the natural next step in spreading technology to the billions of eager and ready potential users of MOP armed with their mobile phones. To bring computing to MOP and implement SLN for largely rural, often illiterate masses requires multimedia-dominant environments that reflect a deep understanding of and respect for unique cultural needs and user requirements.

Some of the recent developments are a strong step in the direction of bringing mobile phone based computing to MOP. An environment that relies on audio, video, and touch (which is now the primary mode in smart phones) input and output and on interface mechanisms that considers cultural practices is the way to make even illiterate casual user to become a creator and consumer of content in multimedia form. Smart phones have brought these modes now to mainstream for the TOP, and all we need to do is to extend these for the MOP. Another major barrier in creating and consuming content by masses in MOP is to bring SLN to mainstream for them is use of different languages. Fortunately, we are at the time when speech input and automatic translations are progressing very fast and the first generation translation systems are already in use on smart phones [20].

Clearly, all technological ingredients are getting in place. What is required is to be innovative and develop systems that would allow emerging phones used by MOP to become usable as a device for building SLN.

## 7. User engagement

One of the most important issue and frequently cited bottleneck [5, 6] in social (life) networks is that of motivating the users to *engage with* and *contribute to* the common resource pool.

We argue that the issue of user motivation is basically that of *value creation* by the process. Simply put, the *action of engagement/ contribution should lead to some value addition to the contributor.*

The value creation can be extrinsic or intrinsic, and *shared* or personal. While other terms may be self-explanatory, we define *shared* as something in which the benefits are accrued to a common pool, and all users (including the contributor) have access to that common benefit (e.g. wikipedia) as opposed to personal benefits (e.g. a discount voucher) in which only the individual user accrues benefits. Also note that there can be aspects in each category which can be quantifiable or non-quantifiable.

Based on influential works like [4], user studies [3, 5, 6], and our own thinking in this direction, we list the following factors which can cause users to contribute to social (life) networks.

### *A) Personal Intrinsic value creation*

This is the category, where the act of engagement/contribution is the reward in itself i.e. the users are doing it for themselves. This includes:

***1) Fun:*** when the users perceive the activity as fun. Examples include ESPGame[21], LOLcats[4], and 'Bored-at-work-networks'[22].

***2) Social connections:*** In many networks, especially those with strong symmetric relationships, users engage basically for their need to interact with loved ones. The fact, that the same inputs (e.g. Facebook updates) can be re-purposed for other uses (e.g. Election outcome prediction) is unimportant from the contributor perspective.

***3) Self-actualization:*** The users also may have an intrinsic need to express themselves, and gain personal utility out of the process. While traditionally blogging was more geared towards self-expression, microblogging and social network posts tend to be more geared towards a social 'show-off' based actualization.

***B) Shared Intrinsic value creation***

This is the category, where the act of engagement/contribution is perceived as that of creating a *common good* for public consumption. The value accrued is available to all at large including the contributors themselves. These structures typically tend to be intrinsic.

***4). Cause***: when the users perceive value by contributing to a (social) cause they believe in. Example includes online activism (e.g. [9]), fundraisers, and tweets in Iran or Egyptian revolution.

***5). Fan following:*** Instead of causes, the users may sometimes perceive value by contributing to commonly held interest, celebrity, or object. Examples include 'Eternal Moonwalk'[23] and Manchester United Fan clubs.

***C) Personal Extrinsic value creation***

This is the category, where the act of contribution results in extrinsic personal benefits directly or indirectly.

***6). Returns on contributions:*** The users may choose to contribute if it leads to clearly observable 'returns' i.e. they can access locked out features, obtain health recommendations, emergency alerts, see global statistics, or increase download quota in P2P networks.

***7) Social benefits accrual:*** The users may choose to contribute if they perceive they are contributing to a virtual deposit box, from which can withdraw when need arises. The idea is basically same as social tit-for-tat. We classify indirect professional benefits also into this category. Many Yelp, and couch-surfing [24] contributors identify with this notion.

***8) Explicit incentivization:*** The users may also engage with social media if doing so grants them explicit incentives e.g. Discount vouchers for Facebook 'Likes', Groupon deals, free burger for online review, or even precise payments for Mechanical turk etc.

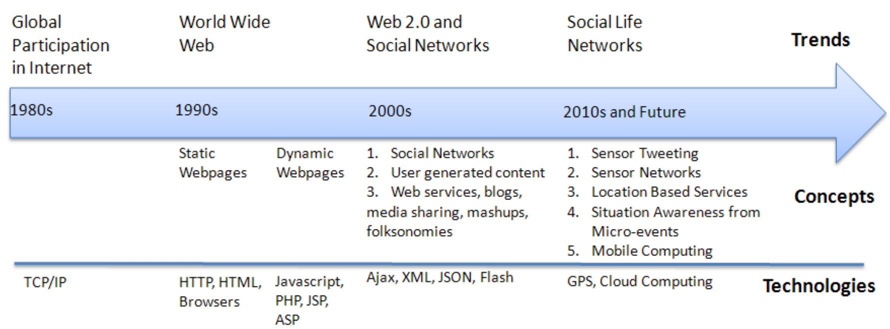


**Figure 8: Evolution of the web**

***D) Shared Extrinsic value creation***

This category is not well documented or studied as it is typically not practical to have an extrinsic valuable resource which can be freely shared by all the members of community.

Note though that each of these categories in turn has quantifiable and non-quantifiable components and can form an interesting research field on its own. We have started taking the first concrete steps in formalizing and studying the problem for *personal extrinsic incentivization* case dealing with *quantifiable* resources.

We define a model [25] which studies how users' modeled as *rational* (selfish) agents would contribute to a common resource pool. We employ a game theoretic formulation and study the rational equilibrium behavior from both an end user as well as system designer perspective.

First problem studied is that of individual contribution strategy. Given a shared social media task (e.g. reporting a suspicious bag at subway), ***n*** agents each with their own costs ($\boldsymbol{C_i}$), and a common shared gain ($\boldsymbol{G}$), how often should the individual user undertake the task herself ($\boldsymbol{P_i}$). The solution to the problem lies at the maximization of individual users expected utility i.e.

$$\underbrace{argmax}_{P_i \in [0,1]} EU_i = f(c_i, G, P_i, P_{Do}^{All-\{i\}})$$

More details are available in [25], but note that the ideal solution for each agent is when they don't undertake the task themselves but *somebody else* does it. Of course, if everybody takes that approach then *nobody* undertakes the task and everybody looses (just like 'prisoners dilemma'). The net solution thus lies at the Nash equilibrium point from which no user has any motivation to deviate.

While a number of 'individually rational' decisions make sense for individual users, the overall system performance is typically not optimized by this (e.g. as documented in the 'tragedy of the commons' [26]). Hence, the second problem studied is that of *mechanism design*[27] from a system designer perspective. Mechanism design deals with analyzing what conditions can the system designer impose on the '*game*' so as to lead it on to certain desired outcomes. Hence, we studied a case where a system designer is open to placing certain *value propositions (e.g. bonus incentives)* to the contributing agents. While the system designers want to put in place *enough* incentives such that the task gets completed, they do not want to give very high bonus such that it actually hurts the overall system utility.

An important point to note though is that the system designers can exploit the advantage that the benefits granted (e.g. extra levels /features, virtual gifts, additional bandwidth, badges/ titles/ memorabilia) are typically just 'fairy gold dust', and physically cost much less than the value perceived by the user.

While we have taken the first steps, clearly there are numerous open research problems in modeling and devising newer ways of engaging users in SLN.

## 8. Current Status and Future Directions

We believe that SLN are the natural next stage in the evolution of networks. In Figure 8, we show steps in the evolution of networks based on progress in computer related networking technology. Current Social Networks are the result of progress in technology convergence of processing, multimedia, bandwidth, Web 2.0, and storage technology. In the last few years the nature of SN has started changing due to rapid advances in hardware going into mobile phones, GPS, camera, speech recognition, touch interfaces, sensor networks, and internet of things. For addressing agriculture related problems for farmers in remote parts, a system called mKrishi [31] is developed by TCS. This system uses mobile phones and several sensors in field to connect farmers to experts in helping to resolve their problems.

Availability of information on Twitter, Facebook, and Flickr (among several others) have encouraged researchers to explore aggregation and processing techniques leading towards situation awareness. We believe that by considering some applications that will connect people and resources, very important systems could be developed for helping not only people in the developed world, but also the middle class of the world that we call MOP.

In this paper, we discussed some approaches that are being actively explored in our research group. We presented some results of these approaches that are discussed in details elsewhere. There are presented to show our thinking and current status of our efforts in building social life networks for middle of the pyramid (SLN for MOP).

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