A Voice for the Voiceless: Peer-to-peer Mobile Phone Networks for a Community Radio Service

Kavitha Ranganathan
Ankur Sarin

W.P. No. 2011-05-02
May 2011

INDIAN INSTITUTE OF MANAGEMENT
AHMEDABAD-380 015
INDIA

A Voice for the Voiceless: Peer-to-peer Mobile Phone Networks for a Community Radio Service

Kavitha Ranganathan[1]
Ankur Sarin[2]

Abstract

We propose a new application for mobile ad-hoc networks (MANETs) – community radio. We argue how MANETS help overcome important limitations in how community radio is currently operationalized. We identify critical design elements for a MANET based community radio service and propose a broad architecture for the same. We then investigate a most critical issue– the choice of the network wide broadcast protocol for the audio content. We identify desired characteristics of a community radio broadcasting service. We choose and evaluate eight popular broadcasting protocols on these characteristics, to find the protocols most suited for our application.

Key Words: Ad-hoc network, mobile phones, user-generated content, community radio

[1] Faculty, Computer & Information Systems Group, Indian Institute of Management Ahmedabad (corresponding author, email: kavitha@iimahd.ernet.in)

[2] Faculty, Public Systems Group, Indian Institute of Management Ahmedabad (email: asarin@iimahd.ernet.in)

A Voice for the Voiceless: Peer-to-peer Mobile Phone Networks for a Community Radio Service

1. **Introduction**

Ad-hoc wireless networks work on the simple principal of devices (including laptops, PDAs and phones) being able to communicate with each other directly and more interestingly act as routers for each other's data. Two devices which are out of range from each other can communicate via an intermediary, which is within range of both. Thus a group of such devices, without any centralized administration or control can form an ad hoc network among themselves, often known as an 'ad-hoc mesh'. When such devices are mobile, the resulting network is popularly called a MANET (Mobile Ad Hoc Network).

Conventional applications for MANETs have been in the area of disaster recovery (when the regular network connectivity like broadband or cellular coverage is non-functional) or military operations (where devices need to communicate with each other in hostile terrain). More recently, MANETs consisting of simple mobile phones have been proposed as an alternative means of village telephony. Vast rural areas in developing regions are "off the Grid", meaning there is no broadband, copper or cellular connectivity available in these regions. Reasons for this are mainly economical – the demand and purchasing capacity of these far-flung and sparse populations do not justify the costs of laying wire or providing cellular tower based coverage. It is for these populations that MANETS are being explored as an alternate means of telephony.

At least two initiatives, the Serval project [11] and TerraNet [12] a Swedish telecom company are exploring the use of mobile phones to construct an affordable village level telephone network. In the Serval project which uses wi-fi to construct an ad-hoc IP based network, special software is used to enable any off-the-shelf mobile phone. Their experiments show that phones can be located a few hundred meters away from each other, and end-to-end voice quality can be sustained through five intermediate hops. TerraNet phones on the other hand contain special proprietary hardware that enables two phones to talk to each other directly if they are within a kilometer of each other and can supposedly route calls through 7 intermediate hops, beyond which the voice quality becomes inadequate.

Users would be required to buy a basic low-end mobile phone pre-loaded with the required MANET software. If there are enough such users, the phones will automatically form an ad-hoc network among themselves, enabling users to talk to one another and exchange other forms of data. This architecture is in contrast to cellular telephony where all communication is routed through base-stations. Figure.1 provides the contrasting architectures of a MANET versus conventional cell-tower based telephony.

We propose a new application for MANETs – community radio. After describing community radio and its purposes, we argue how MANETS help overcome important limitations in how Community Radio is currently operationalized. We then go on to evaluate the feasibility of using MANETs for a community radio service. Although there are many elements involved, in this paper we investigate a most critical issue – the choice of broadcast algorithm.

We envision a true peer service where any participant of the peer-to-peer network can be the source of audio content. This entails that each phone be able to reliably and efficiently broadcast voice-based data packets to every other node in the network. Though there has been considerable research on various broadcast techniques for MANETs, the protocols have been evaluated for different applications and scenarios than the one this paper focuses on. Broadcast packets in MANETs have chiefly been used to discover network topology and build routing tables for packet-routing protocols. Instead, we examine the advantages and limitations of the proposed broadcast schemes in the context of a community radio application and choose the best possible candidates. To the best of our knowledge, our study is the first one to investigate the idea of setting up a community radio service using a mobile-phone based peer-to-peer network.

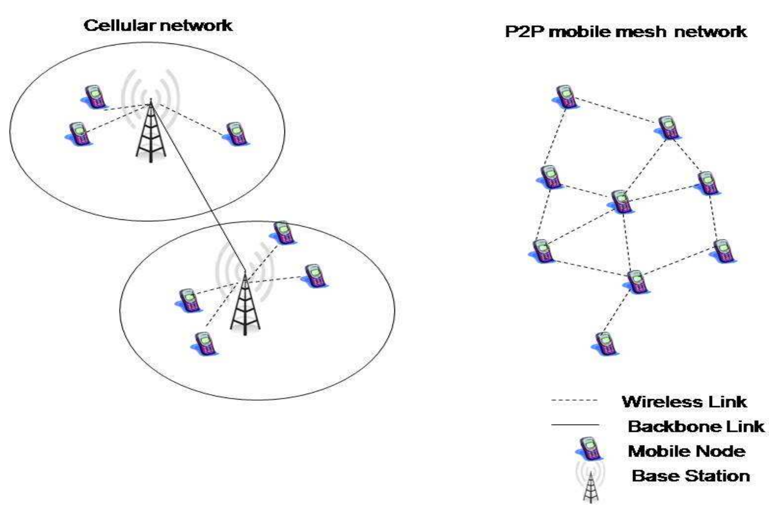


Figure 1: Architecture of a traditional cellular-tower based phone network versus a peer-to-peer phone network.

The rest of the paper is as follows, in Section 2, we introduce the concept of a community radio service (CRS) and describe related work in the field of dissimilating user-generated digital content in rural areas. Section 3 contains our design of a mesh community radio service. In Section 4, we discuss various broadcast techniques for MANETS and group them in four major categories. In Section 5 we introduce desired characteristics of a Community Radio Broadcasting service and evaluate the different broadcasting techniques on this criteria. We conclude in Section 6 with our recommendations and plans for future work.

2. Community Radio and User Generated Content

Community radio has not only been seen as a medium for broadcasting information but also as a means for empowerment via the creation and dissemination of local content. Often it is the only mass medium available to a rural population [Girard (2011)]. The growth of community radio can be gauged by the fact that World Association of Community Radio Broadcasters (AMARC) currently consists of a network of more than 4,000 community radios and supporting organizations in more than 115 countries (www.amarc.org).

Community Radio stations aim to provide a space to :

- allow more people to participate in the process of creating content
- increase the diversity of voices participating in the process
- enable the expression of divergent ideas and values
- bring forth issues that might be more localized in nature or be relevant to a narrower group of people than mainstream media.

Active participation of all members is the key mechanism by which community radio is said to empower the community. It is not only about the content or information but also the act of producing and sharing that content which is empowering. In a recent experiment which allowed participants in a rural village to record advertisements that could be heard by the entire community, an overwhelming majority said they used the service because they wanted to "speak out"[13]. In another study based on the functioning of community radios it was found that the more heterogeneous the group of volunteers, in terms of age, gender and background the more successful the radio station [23].

Community Radio is supposed to be the 'means of expression of the community, rather than for the community' and ' the media to which members of the community have access…when they want access' [16]. Some efforts have tried to make the radio process interactive with programs created around user call-ins and experiments have been attempted to create and disseminate local user generated content [13,14]. However, in most community media, the content is still filtered and distributed from a centralized source – for both technological and managerial or organizational reasons. For example, community radio is broadcast from a centralized radio station using technology that requires (albeit minimal) training. In most cases there is also a process of selection of those who would have the privilege to create, filter and distribute content. It is likely that the more educated, confident or technology friendly people are likely to self-select themselves as generators of content. Although unintentionally, this immediately creates barriers for participation. It separates the producers from the listeners or viewers and in doing so has the potential to "other" them from the very community they are supposed to be a part of.

Our model of a peer-to-peer phone based community radio service, by its very nature of being totally decentralized, aims to avoid the problems of centralized content creation or filtering. Any community member is equally equipped to air their content on the radio service, without a central authority choosing or filtering the content.

If the World Wide Web is a guide it would be foolish to predict the uses of a peer to peer community radio service. However the following usages would not be beyond the realm of possibilities:

- Prose, poetry, songs and plays in local language or dialect and thereby helping preserve them
- Exchange of traditional knowledge passed on orally from one generation to another: e.g. recipes, health and home tips, agricultural practices
- Advertisements for goods and services
- Organizing travel to/ requests for goods and services from neighboring cities
- Classifieds
- Competitions around local talent (akin to India Idol or Britain's Got Talent[3])

2.1. Related work in Local Content Generation

Two alternate solutions for local content creation and sharing in rural areas have been proposed recently, VoiKiosk and AIR.

[3] Bundeli Idol, a singing competition based on local folk songs was a very successful program championed by Radio Bundelkhand, a community radio initiative championed by Gram Vaani [24].

VoiKiosk, a voice-based kiosk solution [13, is accessible by phone and thus suitable for deployment in rural, non-literate populations. The system requires a centralized server that stores voice content. Any user can access this server via a phone and leave their own voice-based advertisement. Users can dial-in to hear content in different categories. The centralized content repository is monitored and can be modified by the kiosk operator.

While the purpose of the VoiKiosk, comes very close to our philosophy of providing a voice for everyone, its implementation differs on two dimensions . Firstly, it requires a central server that is administered by a central authority, the kiosk operator, who has the power to modify any content. In contrast, one of the essential elements of our design is to ensure a totally decentralized system with no hierarchies. Secondly, the VoiKiosk relies on an existing telephone network, which automatically excludes remote regions which are off "the grid" and are expected to remain unconnected for the near future.

Sterling et.al. [14] propose an interactive community radio station model (AIR), that uses specially designed devices that can record voice responses (feedback to radio programs) and automatically relay it back to the radio station. These responses are then used to design subsequent radio content. Devices can relay voice-content to other devices, similar to a MANET approach, but do so in an asynchronous fashion, with the end-goal of eventually reaching the radio-station. AIR's data routing approach assumes a delay-tolerant network since the data can reach the station after a considerable lag since it might only be used for the subsequent day's program. In contrast, the voice-data in our network needs to be broadcast to all nodes in a synchronous fashion and hence both efficiency and reliability are of paramount concern. While AIR is designed for rural areas with no other communication infrastructure [akin to our assumption], it still relies on centralized content filtering and decision making, which is unlike our design philosophy.

3. Architectural Design for Mesh Enabled Community Radio

While using MANETS for a community radio service can enable more users to participate in content generation, the following design concerns related to the decentralized nature of the system emerge.

1. Which user will be allowed to broadcast their content at a given time? How do we avoid collisions and conflicts?

2. Since anyone is allowed to air their content without any filtering, how do we ensure that sanitized content is aired. Who decides what is sanitized content ?

3. Without complete knowledge of the network of phones, how can the content (audio-packets) be efficiently broadcast to all users in the system?

For deciding which user is allowed to broadcast at what time, we propose that weekly physical meetings be held in the village, where all users interested in an air-slot can participate. A weekly schedule can be drawn-up democratically -- a simple table of node-identities (phone numbers), start times and end times. This table could then securely be broadcast to all nodes and stored in each phone's memory. When a user tries to broadcast content, it is only forwarded to other nodes if the schedule permits it.

The issue of unfiltered content is trickier, since a central authority blocking any content might lead to unwarranted censorship. Since this is a community radio, we need mechanisms to allow the community as a whole to decide what content is allowed on their radio service. We envision a decentralized reputation based scheme similar to those used by internet based peer-to-peer file sharing networks [18, 21, and 22 and ad-hoc networks [19, 20]. In such systems, users keep track of past behavior of their peers and allow or disallow participation of peers depending on their reputation.

We provide an overview of the components and data-flow in our mesh community radio in Figure 2. The figure illustrates the flow of the audio content from the source, through an intermediary node (recipient 1), who re-broadcasts it to recipient 2.

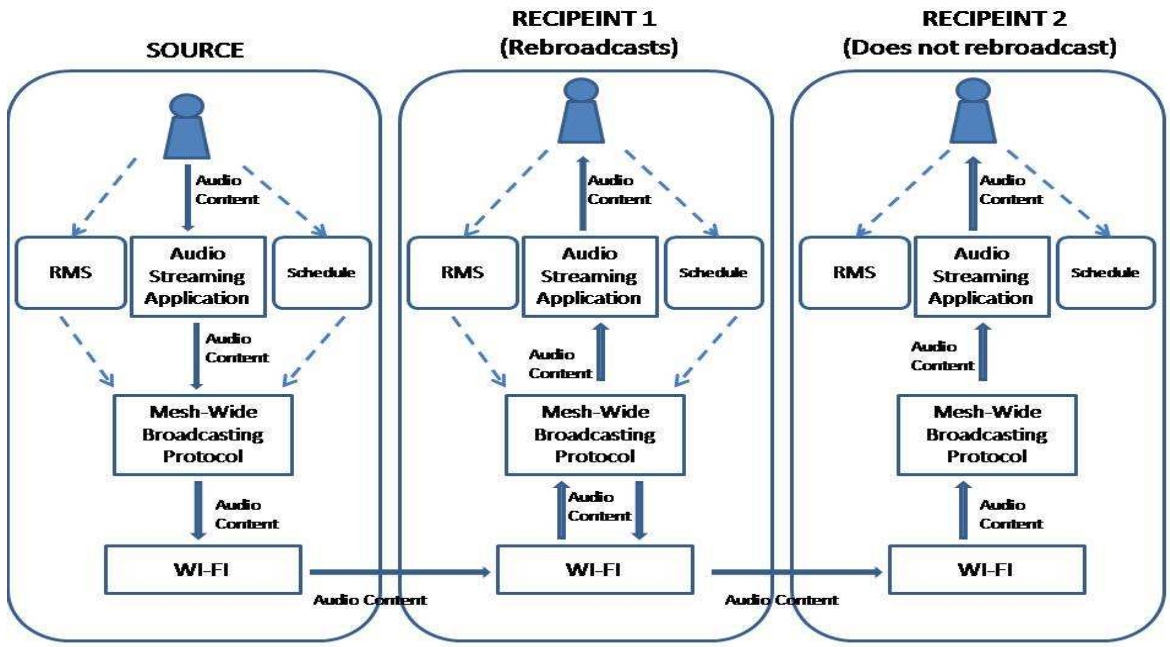


Figure 2: Flow of audio content between three nodes in the mesh network. The audio content is generated at 'Source' and reaches Recipient 1, who rebroadcasts it to Recipient 2.

Each node contains several components as illustrated: the audio content generator (could be the user herself, the RMS – (Reputation Management System), the Program Schedule, the broadcasting protocol layer and the underlying Wi-Fi layer for communication among nodes.

Within a node, the audio content flows from the user to the streaming application, which channels individual packets to the broadcast layer (note that any common VOIP/streaming application can fit in here). The broadcasting layer uses its protocol rules, in addition to information from the schedule and the reputation management system, to decide whether to rebroadcast the data.

The data then flows to the WI-FI layer and is transmitted to nodes within range. At the recipient node, the data is channeled upwards to the user, via the streaming application. The broadcasting layer simultaneously decides whether to re-broadcast the data.

In an earlier paragraph, we have briefly described possible implementations of the reputation management system and Schedule. While these are important components of the community radio system, a detailed discussion of these components is beyond the scope of the current paper. The rest of this paper focuses on the third issue, namely of efficient broadcasting of audio content.

4. Mesh Broadcast Techniques

A network-wide broadcasting technique has two goals - reliability and efficiency. By reliability, we mean that the intended data successfully reaches all nodes in the network. Efficiency means that the least number of re-broadcasts achieve the first goal of reliability. The simplest method involves each node re-broadcasting all packets to all its neighbors and so on, till all nodes receive the packet. More sophisticated broadcasting techniques try to reduce the number of redundant re-transmissions at the cost of increased algorithmic complexity.

While a large number of MANET broadcasting protocols have been proposed in the past, they can broadly be grouped under four categories as identified by Williams and Camp [1]: Simple Flooding, Probability based methods, Area Based Methods and Neighbor Knowledge Methods. Note that the four categories are ordered in increasing amount of complexity. We only consider protocols that are truly distributed in nature, which excludes hierarchical and cluster-based schemes. We now describe one or two representative protocols under each category.

Simple Flooding: The simple flooding technique [3,4] starts with the originator node[4] sending its data to all its neighbors. The neighbors then re-broadcast the data exactly once to each of their neighbors and so on, till all nodes are reached. However, this process may involve a high number of redundant re-broadcasts. If the network in question is dense and/or the data packets are large in size, the extra redundancy can easily cause congestion in the network.

Probability Based Schemes: Two techniques – probabilistic scheme and counter-based scheme allow nodes to re-broadcast based on the network topology. In the **probabilistic scheme** [5], nodes re-broadcast only with a certain preset probability. In dense networks where multiple nodes may have common coverage, if some nodes do not re-transmit the network will not suffer. On the other hand, in sparse networks with less or no overlap in node ranges, the probability level will have to be set higher, so that all nodes receive the packet.

The **counter-based scheme** [5] works on the intuition that there is an inverse correlation between the number of duplicate packets (henceforth called redundant packets) a node receives and the chances that the node can reach additional new nodes by re-broadcasting. Hence, when a node receives a new packet, it waits for a certain amount of time (called the RAD[5] time) before deciding whether to re-broadcast. During the RAD time, it keeps a count of the number of redundant packets received. If the count exceeds a threshold then the packet is not re-

[4] In the rest of the paper we use the term 'nodes' to refer to individual phones in the p2p network.
[5] The short interval of time that a node waits for duplicate packets, before re-broadcasting is termed as the 'Random Assessment Delay', in [1] and we use the same terminology. The RAD is randomly chosen from a uniform distribution between 0 and the highest allowed time delay for re-broadcasting.

broadcast. The counter-based scheme ensures that lesser nodes re-broadcast in denser parts of the network, and more nodes re-broadcast in the sparser regions.

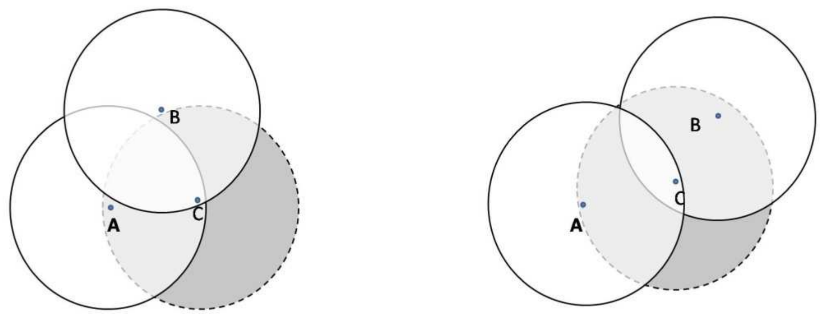
A hybrid of the probabilistic and counter based methods (which we call **Dynamic-Prob**) is proposed by Zhang et al. [7]. Dynamic-Prob dynamically adjusts the probability of re-broadcasting at each node, depending on the number of redundant packets a node receives. Thus in sparser parts of the network, the probability of re-broadcasting is set to a lower level than in denser parts of the network. Since the re-broadcasting occurs as soon as a packet is received and not after the RAD time expires as in the counter-based scheme, the latency of the hybrid algorithm is lower compared to the counter-based approach.

Area Based Schemes: Area based schemes try to estimate how much additional area-coverage will be achieved by a re-broadcast, the intuition being that two nodes which are very close together will have roughly the same coverage. Note however that the estimate is only for the area and not the number of nodes in the area. Two variants in this category are the distance-based and location based schemes.

In the **distance-based scheme** [5], when a previously unseen packet arrives at a node, and the source is more than the predetermined threshold distance away, a RAD is initiated. At the end of the RAD, the distance between the node and each of the sources of redundant packets is checked. If any of the distances are less than the threshold, the packet is not re-broadcast. This authors of this scheme suggest that since the signal strength at the receiver is inversely proportional to the distance traveled by the signal, it (the signal strength) can be used to calculate the distance of the source node.

The location based scheme [5] aims to be more accurate in its estimation of additional area coverage by a re-broadcast. Each node transmits its exact position (latitude and longitude) as part of the data packet. When a node receives a new packet it initiates a RAD. The node uses the location of each source node of a redundant packet received during the RAD interval, to calculate how much of its own coverage is not in the set of the combined areas of all the source nodes. If the additional coverage gained is below a certain pre-defined threshold then the packet is dropped. At the end of the RAD, if the additional coverage is more than the threshold, the packet is re-broadcast. Figure 2 illustrates the working of the location-based scheme with three nodes. The authors suggest that GPS (Global Positioning System) technology can be used to obtain the location of a node.

Neighbor Knowledge Schemes: Nodes using this approach try to estimate how many unreached nodes their re-broadcast will contact. We consider two protocols under this scheme: the Scalable Broadcast Algorithm and the Ad Hoc Broadcast Protocol.



(a) **(b)**

Figure 3: Location-based scheme - Node C receives the same packet from A and B and calculates additional area not covered by both (shaded region). (a) Additional coverage is above threshold so C decides to re-broadcast (b) Additional coverage is below threshold so C does not re-broadcast.

The Scalable Broadcast Algorithm (SBA) [6] uses its two-hop neighborhood knowledge to decide whether to re-broadcast. "Hello" messages are used to obtain the two-hop neighborhood knowledge. Each node sends a "hello" message with its own identity and a list of its one-hop neighbors to all its neighbors. This provides each node with the two-hop topology of nodes centered around itself. When a new packet arrives, the node checks to see if any of its neighbors are not already covered by the source node. If new neighbors are discovered, a RAD is initiated . If during the RAD interval, other redundant packets arrive, the node again checks to see if any neighbors are still unreached. If at the end of the RAD, any of its neighbors are yet unreached, the packet is re-broadcast. Figure 3 illustrates an example of the SBA protocol when (a) a node decides to re-broadcast and (b) when no new neighbors can be reached by a re-broadcast.

The authors of SBA have also proposed a method [6] to dynamically adjusts the RAD to network conditions. Nodes with more neighbors have a proportionally shorter RAD time and hence broadcast before others. This extension helps in increasing the efficiency of SBA.

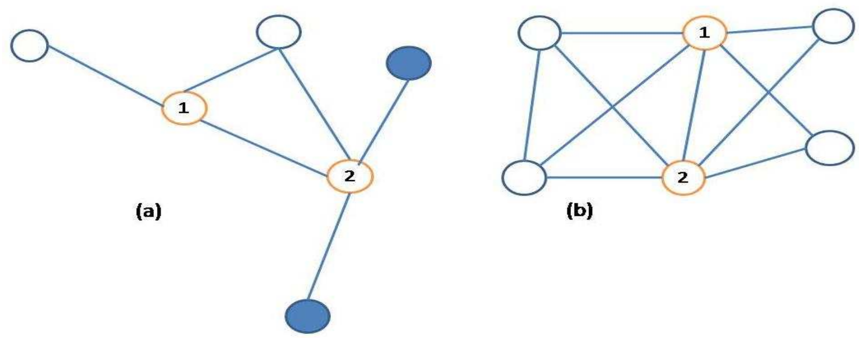


Figure 4: Illustration of SBA protocol : (a) Node 2 re-broadcasts packet received from Node 1, as two neighbors of 2 (shaded) are unreachable by Node 1 (b) Node 2 does not re-broadcast packet received from 1 as no new neighbors are found.

The Ad Hoc Broadcast Protocol (AHBP**)** [8] also uses 2-hop neighborhood knowledge. However, unlike SBA where each node decides whether to re-broadcast, in AHBP**,** upstream nodes decide which down-stream nodes should re-broadcast. Nodes that re-broadcast are called Broadcast Relay Gateways (BRG). Each BRG chooses a subset of its neighbors to act as BRGs. The subset of neighbors is chosen in such a way that all the nodes in the 2-hop neighborhood are covered in the most efficient manner. AHBP incorporates a special feature for adapting to highly mobile nodes. If a certain node receives a packet from a previously unseen node, it (the receiver node) immediately acquires BRG status. The intuition behind this is that, since at-least one of these nodes in new to the neighborhood, the network has changed and additional re-broadcasts can to a degree, counter this change.

5. Assessment

We identify five characteristics which we think are crucial for the success of a network wide broadcast protocol for radio content, built on the platform of a wireless peer-to-peer phone network.

Detailed simulation studies of some of these broadcast protocols, under a variety of network scenarios have been conducted in the past [1,3,5,6,7]. Analytical models have also been used to predict the performance of some of these protocols under specific MANET conditions [2]. We use these studies to glean the performances of the selected protocols, extrapolating for conditions specific for a community radio service.

5.1 Desired Broadcast Protocol Characteristics for a Community Radio Service

We identify the following criteria for a successful broadcast protocol:

Efficiency : Since the broadcast protocol will be used to distribute voice data to all users, the data packets in this system are expected to be bigger than the typical 'hello' packets used in the case of MANET routing protocols. Hence, the efficiency of the protocol is an important factor to keep the network from getting congested – especially if the network is dense. The protocol in question should be able to effectively weed out redundant re-broadcasts. Ensuring lesser re-broadcasts has multiple advantages , not only is network congestion kept in check, the device consumes less power, a commodity in short-supply in many rural areas of emerging regions [25].

Robustness to Mobility : The network under consideration is composed entirely of mobile-phones carried by individual users. Hence, the chosen protocol should be able to adapt to a high degree of mobility in the network.

Adaptability to Network Topology : Our community radio service is targeted towards rural villages. While there is no typical village architecture we can draw upon to infer the possible topology of such a network, some generic assumptions can be made. A typical Indian village for example is divided into various hamlets. A hamlet could be described as a dense cluster of dwellings. Users in the village might typically leave for work to nearby fields or the central bazaar (market) early in the morning. At this point the mobile-phone network can be expected to be sparse and scattered in some regions(fields) and dense in the market-place. In the evening when people return home, the network can be expected to be composed of multiple dense clusters.

Hence, the broadcast protocol should be able to adapt to the local topology which might be dense as well as sparse in different regions and at different times of the day.

Latency : Since the application in question deals with synchronous voice-data, the quality of the transmission is of high importance. Data packets should be transported with minimum delay, to ensure that adequate voice-quality of the service is maintained. Hence the broadcast protocol should strive to minimize latency.

Simplicity : The radio service needs to operate on basic mobile-phones which are the devices that are affordable to many users in developing nations. These devices have resource constraints in terms of CPU power, battery and memory. Hence the protocol in question should be simple enough to operate on these basic devices. Furthermore, special features like GPS may not be available on these devices.

Note that the following dimensions are not necessarily independent of each other – and some tradeoffs among the different parameters might be necessary. For example, a protocol that is highly efficient may require a complicated algorithm to attain that efficiency.

5.2 Evaluation of Broadcast Techniques

We compare the eight protocols described earlier, on the five dimensions described in Section 4.1. Note that none of the past studies that we draw on have evaluated these protocols specifically for the phone-based radio service that we are proposing. We use these studies as a base and extrapolate from their findings for our specific application. Table 1 provides an overview of the comparison of the different protocols, across the five dimensions described earlier.

Table 1: Performance of MANET broadcast protocols on various dimensions

	Efficiency in Dense Networks	**Robustness to Mobility**	**Introduces Extra Latency**	**Adaptability to Network Topology**	**Simplicity**
Simple Flooding	Highly Inefficient	Very Good	No	Low	Very Simple
Probabilistic	Moderately Efficient	Good	No	Low	Simple
Counter-Based	Moderately Efficient	Good	Yes	High	Moderate
Dynamic-Prob	Moderately Efficient	Good	No	High	Moderate
Distance Based	Efficient	Sufficient	Yes	Moderate	Moderate
Location Based	Efficient	Sufficient	Yes	Moderate	Moderate
SBA	Highly Efficient	Sufficient	Yes	High	Complex
AHBP	Highly Efficient	Low	No	High	Complex

Simple flooding is highly inefficient in dense networks. The protocol is well suited for highly mobile sparse networks, where all nodes re-broadcasting all the time, will not congest the network. However, as noted earlier, our network is expected to be composed of dense clusters distributed among parser regions ,thus rendering Simple Flooding as a less desirable choice.

In the **probabilistic scheme**, a fixed probability of re-broadcasting is assumed at each node, which is successful in reducing redundant re-broadcasts to a degree. Earlier work has demonstrated that the optimal value for this probability is around 0.65 [5, 10]. However, it is obvious that this probability will not be the optimum for all parts of a network. In denser regions for example, lesser nodes will be required to re-broadcast thus calling for a probability factor lesser than 0.65. Similarly, in sparser regions, more nodes may need to re-broadcast so that all nodes are reached, requiring a value greater than 0.65. Hence a node following the probabilistic scheme cannot be expected to adapt its behavior to the local topology, rendering it less suitable for our network.

The counter based method [5] is simple yet automatically adapts to the topology of the network : in denser areas lesser nodes re-broadcast and in sparser areas all nodes re-broadcast the packet. However, due to the RAD introduced when a new packet arrives at a node, the protocol incurs a latency in delivering packets. Since latency in delivery is very harmful for the quality of voice data, the counter-based protocol is not suitable for our community radio service.

The hybrid scheme (Dynamic-Prob) [7] is a combination of the probabilistic and counter-based schemes, and has the best of both worlds. It dynamically adjusts the probability of re-broadcasting depending on the local density of nodes. However, the hybrid scheme does not wait for the RAD time-out before delivering a packet - the probability value is adjusted according to the count of the number of redundant packets received earlier. Hence, the hybrid scheme while being moderately simple to execute, is efficient in dense as well as sparse parts of the network, is robust in the face of mobility and minimizes latency. It has good performance on all the desired dimensions making it a promising candidate for our Community Radio Service.

Both the **area-based schemes** while efficient in dense networks, are only moderately adaptable to the network topology – note that they can only predict the extra area covered by a re-broadcast and not the number of nodes. In addition, both these schemes require certain special features for the mobile devices being used. The Distance-Based scheme requires that the signal strength of a communication can be detected at a fine granularity while the Location-based scheme requires each phone to contain the GPS (Global Positioning System) facility. Since the radio service we envision needs to be deployed on low-end phones, we cannot make the assumption that either of these facilities will be universally available on all devices on the network.

The neighbor-based methods (SBA and AHBP) are the most complex, requiring extra 'hello' messages to gather the two-hop topology at every node. The extra complexity has the advantage that both these protocols are highly efficient in weeding out redundant re-broadcasts. However, no clear winner emerges, since each protocol lacks in a different dimension.

While performing well in mobile environments, SBA uses a RAD which means that it introduces extra latency in packet transmissions. AHBP on the other hand, does not introduce extra latency but has difficulty in mobile environments. Since, in AHBP, upstream neighbors decide which down-stream neighbors should rebroadcast, outdated 2-hop neighbor knowledge corrupts accurate decision-making when the nodes are mobile [1].

However an extension proposed for SBA aims to minimize the latency introduced because of the RAD. The intuition behind the extension goes thus - for non-congested networks a low value of RAD is feasible, so that the end-to-end delay (latency) in a non-congested network can be minimized . However a high RAD value is desired for congested networks, to ensure that further congestion is not caused by redundant re-broadcasts. The authors of [1] propose an extension to SBA on these lines - the RAD is adjusted according to the amount of congestion in the network. SBA with the proposed extension (SBA-adaptive) is shown to perform better than normal SBA [1], by minimizing latency when possible.

Hence SBA-adaptive works reasonably well on all the required dimensions, and can be considered a good candidate for a community radio service.

We have thus narrowed down to two candidates - Dynamic-Prob and SBA-adaptive. While SBA-adaptive has a more complex algorithm than Dynamic-Prob and hence might be more difficult to implement and deploy, the rewards are in increased efficiency of the network performance. Of the two, Dynamic-Prob is better suited for a highly mobile network while SBA-adaptive is shown to perform better in very dense networks. Depending on individual network characteristics, one protocol might perform marginally better than the other, though both promise to be robust choices for our application.

6. Conclusions and Future Work

We have conceptualized a new form of creating and broadcasting community radio in this paper. The system we propose is built around the essence of community media – participation by the community. Participation is a term that is much used and maligned in the ICT4D[6] literature. While paying due respect to it notionally, most interventions and programs have found it difficult to give genuine meaning to the idea of participation as one that truly creates democratic spaces [17]. Technology that was often hoped to facilitate participation, instead often creates barriers and new form of hierarchies in communities. The MANET community radio proposed is unique in that the technology is not in opposition to the ideals of community media but is very

[6] ICT4D : Information and Communication Technologies For Development

much a part of the process. It is both the enabler as well as the manifestation of the ideals of community media. Quite simply put, a MANET community radio service simply cannot exist without participation by the community.

In this paper, we identified three critical operational issues that stem from the totally decentralized nature of the conceptualized radio service:

(i) To decide who is allowed to broadcast when, (ii) To deal with unfiltered content stemming from any user, in any part of the network and (ii) To efficiently broadcast the voice-data to all the users, when the network topology is not known by individual nodes, and can change frequently.

We proposed an architectural framework for such a system which uses a Reputation Management System (RMS)to counter unfiltered content and a community-generated schedule for radio programs. While this paper focused on the third issue of efficient and reliable mesh broadcasting, we plan to design and test a scheduling system as well as a reputation based system as part of future work. This will provide an end-to end design solution for a MANET based community radio service.

We identified specific desired characteristics for a broadcast protocol for a community radio service and evaluated eight well-known broadcast schemes on these dimensions. We found that two schemes seem particularly promising for our application: Dynamic-Prob, in which a node forwards data packets probabilistically, but can adapt the probability factor according to the local network topology and SBA-Adaptive that uses two-hop neighborhood knowledge to forward packets, but can adapt to the amount of congestion in the network. Of the two, Dynamic-Prob was identified as better suited for a highly mobile network while SBA-adaptive is shown to perform better in very dense networks. We recommend that both schemes be deployed in the particular MANET using the radio service, before choosing one over the other.

As part of future work, we plan to simulate realistic village level MANET topologies and test the performance of the two protocols under different user-behaviors and mobility patterns.

References

1. B. Williams and T. Camp, Comparison of Broadcasting Techniques for Mobile Ad Hoc Networks, *Proceedings of the ACM International Symposium on Mobile Ad Hoc Networking and Computing (MOBIHOC '02)*, pp.194-205, 2002

2. B. Williams, D. Mehta, T. Camp and W. Navidi, Predictive Models to Rebroadcast in Mobile Ad Hoc Networks, *IEEE Transactions on Mobile Computing (TMC)*, vol. 3, no. 3, pp. 295-303, 2004.

3. C. Ho, K. Obraczka, G. Tsudik, and K. Viswanath. Flooding for reliable multicast in multi-hop ad hoc networks. In *Proceedings of the International Workshop on Discrete Algorithms and Methods for Mobile Computing and Communication (DIALM)*, pages 64–71, 1999.

4. J. Jetcheva, Y. Hu, D. Maltz, and D. Johnson. A simple protocol for multicast and broadcast in mobile ad hoc networks. Internet Draft: draft-ietf-manet-simple-mbcast-01.txt, July 2001.

5. S. Ni, Y. Tseng, Y. Chen, and J. Sheu. The broadcast storm problem in a mobile ad hoc network. In *Proceedings of the ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM)*, pages 151–162, 1999.

6. W. Peng and X. Lu. On the reduction of broadcast redundancy in mobile ad hoc networks. In *Proceedings of MOBIHOC*, 2000.

7. Qi Zhang and Dharma P. Agrawal , Dynamic Probabilistic Broadcasting in MANETs, , Journal of Parallel and Distributed Computing, Volume 65, Issue 2, February 2005

8. Wei Peng and Xicheng Lu, AHBP: An efficient broadcast protocol for mobile Ad hoc networks, JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY, Volume 16, Number 2, 114-125.

9. Michael D. Colagrosso, Intelligent Broadcasting in Mobile Ad Hoc Networks: Three Classes of Adaptive Protocols, ,EURASIP Journal on Wireless Communications and Networking,Volume 2007 (2007)

10. Z. Haas, J. Halpern, L. Li, Gossip-based ad hoc routing, in Proceedings of the IEEE INFOCOM, IEEE Computer Society, New York, 2002.

11. The Serval phone project : www.servalproject.org

12. Terranet: www.terranet.se

13. Sheetal K. Agarwal et al., “User-Generated Content Creation and Dissemination in Rural Areas,” *Information Technologies & International Development; Vol 6, Issue 2 - Summer 2010 (Special Issue: ICTD2009)* (2010), http://itidjournal.org/itid/article/view/518/226.

14. S. Revi Sterling, John O'Brien and John K. Bennett, Air: Advancement through Interactive Radio, Journal of Information Systems Frontiers , Volume 11, Issue 2, April 2009.

15. Sarita Seshagiri, Aman Sagar and Dhaval Joshi, Connecting the ‘Bottom of the Pyramid’ – An Exploratory case study of India’s Rural Communication Environment, Proceedings of the 16th International Conference on World Wide Web Banff (2007).

16. Stefania Milan, “Four steps to community media as a development tool,” *Development in Practice* 19, no. 4 (2009): 600.

17. Bill Cooke and Uma Kothari, eds., *Participation: the new tyranny?* (London: Zed Books, 2001).

18. K. Aberer, Z. Despotovic, Managing Trust in a Peer-2-Peer Information System, in: Proceedings of the IX International Conference on Information and Knowledge Management, Atlanta, Georgia, November 2001.

19. S. Buchegger, J.Y. Le Boudec, The effect of rumor spreading in reputation systems for mobile ad-hoc networks, in: Proceedings of WiOpt '03: Modeling and Optimization in Mobile, Ad Hoc and Wireless Networks, Sophia-Antipolis, France, 2003.

20. S. Buchegger, J.Y. Le Boudec, A Robust Reputation System for P2P and Mobile Ad-hoc Networks, in: Second Workshop on the Economics of Peer-to-Peer Systems, Cambridge, MA, USA, 2004.

21. S.D. Kamvar, M.T. Schlosser, H. Garcia-Molina, Eigenrep: Reputation management in p2p networks, in: Proceedings of the World Wide Web Conference, Budapest, Hungary, 2003.

22. L. Xiong and L. Liu, Peertrust: Supporting reputation-based trust in peer-to-peer communities, *IEEE Transactions on Knowledge and Data Engineering (TKDE), Special Issue on Peer-to-Peer Based Data Management* 16 (2004) (7), pp. 843–857

23. K. V. Vuuren. Beyond the Studio: A Case Study of Community Radio and Social Capital. In Journal of Community, Citizen'sand Third Sector Media and Communication (3CMedia), November 2001.

24. Zahir Koradia, Balachandran Chandrasekharan, and Aaditeshwar Seth, Understanding and Meeting the ICT Needs of Community Radio Stations, Feb 2010.(accessed from http://www.cse.iitd.ernet.in/~aseth/act4d/reports/grins-community-radio.pdf)

25. Eric Brewer, Michael Demmer, Bowei Du, Kevin Fall, Melissa Ho, Matthew Kam, Sergiu Nedevschi, Joyojeet Pal, Rabin Patra, and Sonesh Surana , The Case for Technology for Developing Regions. . IEEE Computer. Volume 38, Number 6, pp. 25-38, June 2005.