

Hybrid Content Forwarding Technique for Bluetooth Communication Environment

⁴Sardar Kashif Ashraf Khan, ¹Jonathan Loo, ¹Muhammad Awais Azam, ²Humaira Sardar, ³Muhammad Adeel, ³Laurissa N Tokarchuk

¹School of Science and Technology, Middlesex University, London, UK

²Department of Software Engineering, Fatima Jinnah Women University, Rawalpindi, Pakistan

³School of Electronic Engineering and Computer Science, Queen Mary University of London, UK

⁴Department of Electrical Engineering, Mirpur University of Science and Technology, Mirpur AK, Pakistan
ska.khan@must.edu.pk, {j.loo, m.azam}@mdx.ac.uk, {muhammad.adeel, laurissa.tokarchuk}@eecs.qmul.ac.uk

Abstract— In opportunistic networks, content forwarding is an exciting challenge due to no direct knowledge of routes to intended destinations. Forwarding decision is often based on node's local information or information provided by the encountering nodes to reduce the communication cost. This paper presents an orthodox yet unexplored approach for efficient content forwarding in Bluetooth communication environment. The new approach combines the characteristics of two different routing techniques, 1) social centrality based forwarding techniques used in opportunistic networks where nodes are sparsely exists, 2) traditional mobile ad-hoc networks (MANETs) protocols where proximity of nodes are close enough to form ad-hoc networks; hence named as Hybrid Content Forwarding Technique (HCF). The experimental results have shown that HCF not only improves the overall delivery ratio and delay but also reduces communication cost. Moreover, HCF efficiently adapts its forwarding technique according to network conditions.

Keywords- Content forwarding; MANETs; AODV; Social Networks; Forwarding algorithm; Opportunistic routing; Ad-hoc communication; Human relationships

I. INTRODUCTION

Mobile phones are so common these days, almost everyone carries one. Most of the mobile phone are now equipped with Bluetooth technology and each mobile phone has a unique Bluetooth ID in the world. This uniqueness makes a mobile phone ideal for ad-hoc communication in single and multi-hop environments. Bluetooth technology can be used as a cheap communication medium for information sharing (i.e. SMS or emails) or in situations where main telecom infrastructure is not available (i.e. disasters).

Many researchers [1, 2, 3] have proposed different algorithms for successful content dissemination in opportunistic networks and mainly these algorithms are simulated or experimented in Bluetooth communication environment. In opportunistic networks there is no prior knowledge of routes to the intended destinations. In order to forward messages in the network, nodes have to rely on local information or the information provided by the encountering node. Therefore, the primary task in these networks is to delivery content to the destinations with minimum communication cost. Epidemic [2] uses the concept of

control broadcasting by not transmitting same packet twice to the same node. However, it still has a huge communication cost. On the other hand, Bubble Rap [1] is a social forwarding based algorithm addresses this issue by selecting forwarding node on the basis of popularity. Similarly, PeopleRank[3] inspired by Google's PageRank[4] measures the relative importance of the person within the network for ranking. By targeting higher PeopleRank nodes a significant reduction in communication cost is achieved. Almost all of these opportunistic algorithms considered one-to-one node communications, where nodes communicate using Bluetooth with only one encountering node at a time. However, one-to-one communication is not the only option; nodes can also communicate using single or multi-hop formation via bridge nodes in Bluetooth communication environment.

In Bluetooth, multi-hop communication can be realised by the formation of piconet or scatternets. Mobile ad-hoc networking (MANETs) protocols such as Adhoc on Demand Distance Vector (AODV) or Destination-Sequenced Distance Vector (DSDV) are used in scatternets for route learning to the intended destinations. In piconet one master and seven slave nodes are allowed, master node has to play an important role as a central entity. In scatternet, more than eight nodes form multiple piconets and communicate each other via bridge node; bridge node has a key responsibility as a communicator among two piconets. Scheduling performance [5, 6] of the master node dictates the efficiency of a piconet. Whereas, not only scheduling performance of master node but also performance of bridge node does play an important role for overall efficiency of scatternet. Several bridge algorithms have been proposed [7, 8] for Bluetooth nodes acting as a bridge node in scatternet. In [9] Law et al proposed an efficient scatternet formation algorithm to minimise inter-piconet interference and avoid bottlenecks.

In this paper, we present an approach where an effort is made to combine two different yet related ad-hoc communication approaches such as scatternet formation and social forwarding algorithms. For this purpose, the emphasis of this paper is to make the routing and content dissemination more efficient by keeping Bluetooth protocol stack and human social relationship patterns in mind. Two well-known algorithms Bubble Rap (BR) [1] and scatternet formation algorithm [9] are combined to form a hybrid content forwarding (HCF) approach. This new hybrid

approach is tested against BR in simple movement model using NS-2 simulator. Experimental results have shown that such hybrid approach not only increases the overall message delivery but significantly reduces the communication cost. Moreover, a significant decrease in delay is also observed.

The paper organized as follows: Section II gives the background and related work. Section III details the concept of the hybrid content forwarding. Section IV discusses the hybrid content forwarding architecture. Section V provides the experimental results and discussion. Section VI gives our conclusion with a discussion of future work.

II. BACKGROUND AND RELATED WORK

Piconet: When two devices form a Bluetooth connection, one takes the role of master and other takes the role of a slave, this formation is known as piconet. In a single piconet, a master node has maximum of up to seven slave nodes. The master node is the central entity of a piconet and slave nodes can only communicate via master node in a given piconet. The nodes present in a single piconet use the same physical channel; this means that devices have to synchronize to a common clock and hopping sequence. In order to accommodate different slaves in a single piconet, master node has to schedule time slots and in a dedicated time slot a slave node can transmit its information via master node. For this reason, each slave node has to synchronize its clock with the master node and hopping sequence is determined from the master's clock and it's Bluetooth ID. The efficiency of a piconet directly depends on the scheduling performance of the master node. More efficient and accurate is the scheduling more quickly data can transmit from source to destination in a piconet. Many algorithms [5,6] have proposed different polling schemes for the efficient scheduling of master node.

Scatternet: Different piconets can coexist in a given location, each piconet has its own physical channel (meaning that independent piconet clock and hopping sequence), which is derived from respective master node. Since each piconet has its own dedicated channel, the packet transmitted on a given channel is preceded by the channel access code derived from the master device address. As number of piconets increase in a given area, the probability of collision and performance degradation increases due to the sharing of the same frequency range. By implementing time multiplexing, a Bluetooth device can participate in two or more piconets. If a node is acting as a bridge node between two piconets, such kind of formation is known as scatternet. A device can only act as a master in a single piconet but can be a slave in several other piconets. A slave node participating in two different piconets must have to synchronize with the clocks of master nodes in respective piconets (since two master clocks drift independently), for this purpose slave node has to add and maintain (regular update) two offsets in its own native clock. The core Bluetooth specifications [13] do not define any functionality for scatternets. The Bluetooth core protocols only define the basic configuration of a piconet. In order to create routing capabilities in scatternet, it is the responsibility of higher level protocols such as logical transports, logical links and

L2CAP channels to provide capabilities for the transport of data. Several bridge algorithms have been proposed [7, 8] for Bluetooth devices acting as a bridge node between two different piconets.

Opportunistic Forwarding algorithms: In [1] author presented an algorithm known as Bubble Rap, where popularity is given to each node according to its social activeness. The idea is to transfer messages to more popular nodes; this will lead to the successful delivery of messages to its destination. Another interesting idea in [10] is that a person has a strong influence in a society if it has more connections such as diplomats who want more influence in a society but want fewer prices to pay in terms of cost i.e. making personal relationships or spending time. On the same lines, another concept known as lobby index [11] inspired from the diplomat dilemma i.e. a node has high lobby index if it has neighbors having at least equal or more neighbors than node itself in current communication environment. This means that a node having high lobby index can refer to those nodes which have high connections, thus reduces communication cost. Similarly, PeopleRank[3] measures the relative importance of the node in the network for node's ranking. This concept is adopted from the Google's PageRank [4], where it gives ranking to the websites for priority. By prioritizing nodes, PeopleRank significantly reduces the communication cost of the network.

The rest of the paper presents our hybrid content forwarding technique and protocol architecture.

III. HYBRID CONTENT FORWARDING

To understand the HCF approach, consider the scatternet formation in figure 1. The source node is present in Piconet '1', destination node is initially present in piconet '2' and the highest social ranked (popular) node present in piconet '4'. The destination node joins and leaves different piconets after specific interval of time as depicted in figure 1. Initially, source node is sending messages to the destination node in piconet '2' using traditional MANET protocol such as AODV. After sometimes destination node leaves the network, at this point source node switch it on opportunistic forwarding technique and relies on social forwarding algorithm and starts looking for most popular node in the network. By the help of AODV protocol it locates the most popular node such as node '26' in figure '1' and starts forwarding the messages. When destination node rejoins piconet '4' after sometimes, source node start sending messages directly to the destination node and during the absence of the destination node the data which is received by most popular node (node '26') also sends data to the destination node. This kind of hybrid content forwarding approach gives following benefits:

- Hybrid content forwarding allows nodes to adopt one-to-one communication approach using opportunistically forwarding algorithm when very few distanced nodes are present in the network.

However, when a group of nodes is present in the network, the hybrid content forwarding allows nodes to form scatternet and communicate each other using traditional ad-hoc protocols such as AODV.

- In absence of destination nodes, hybrid content forwarding allows source nodes to rely on opportunistic forwarding algorithm and send messages to most popular ones.
- With the help of scatternet, source and most popular nodes can reach to the destination nodes that may join anywhere in the scatternet using traditional MANETs protocols and vice versa.
- In Hybrid content forwarding nodes have the ability to reach those nodes which are beyond their transmission range with the help of bridge nodes in the network.
- In the absence of destination nodes, the source nodes forward messages to the most popular nodes. When destination node returns the source and most forwarding nodes start forwarding the messages to the destination. Due to this approach, a significant increase in message delivery ratio is expected.
- Low communication cost and fewer delays are expected because nodes can now directly reach to the intended destinations using traditional ad-hoc routing algorithms in scatternet environment.

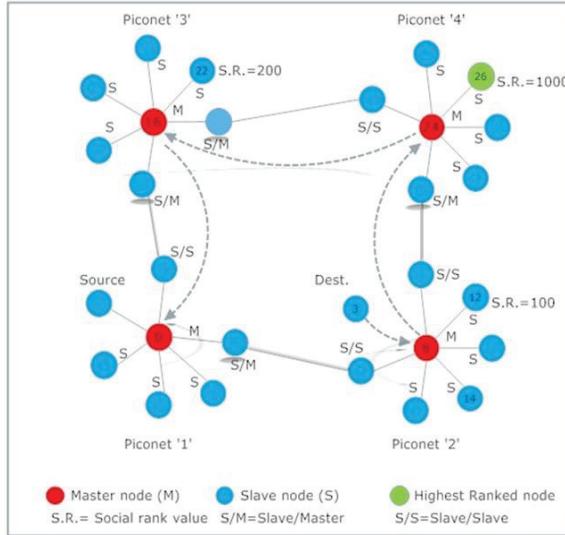


Figure 1. Hybrid Content Forwarding (HCF)

IV. HCF ARCHITECTURE

In human society, people form relationships such as family at home, colleagues in offices and friends, thus have specific patterns in their life. These patterns can be exploited for opportunistic content dissemination as presented in different social forwarding algorithms such as [1] where popularity is the criteria to choose forwarding nodes.

Similarly, it is also possible that during visit to different places such as conferences or some gathering where people may come across with group of other people where they introduced with new friends. In terms of Bluetooth communication environment, such close gathering where many people present in a given area can be reach using scatternet formation of nodes such as presented in [9].

Figure 2 shows the typical architecture of hybrid protocol. In opportunistic network, a node may encounter one node or set of nodes while on the move. This means that when a node encounters only one node than it can rely on opportunistic forwarding technique. In case, when there are multiple nodes present in the area, rather than relying on one-to-one approach of opportunistic forwarding algorithm, a scatternet formation of nodes can be used. Scatternet can be formed to communicate with multiple nodes using MANETs protocols such as AODV or DSDV, within range or even out of range nodes. This kind of hybrid approach gives nodes to gain high reach and knowledge of the network as a result better message delivery with speed and low communication cost can be achieved. The hybrid approach sits on the top of scatternet formation algorithm as shown in figure 2, so any new and better scatternet formation algorithms come in future, will automatically enhance the efficiency of proposed approach.

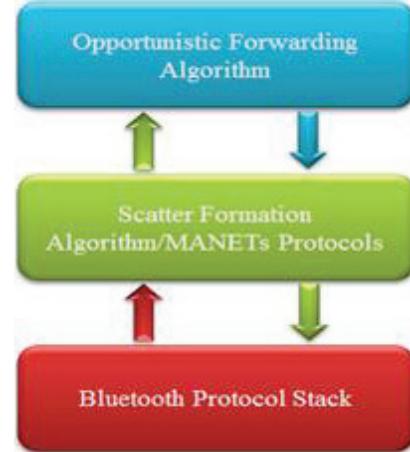


Figure 2. HCF architecture

V. RESULTS & DISCUSSION

A. Simulation Setup

To evaluate the HCF, a UCBT-Bluetooth extension for NS-2 simulator [12] is used for the simulation. UCBT-Bluetooth extension is specifically designed by keeping IEEE 802.15.1Bluetooth protocol stack in mind. The transmission range of each node is 10m and at 2Mbps data rate. Bubble Rap [1] is used as opportunistic forwarding algorithm, therefore, each node is allowed to update its popularity metric upon encounter with other nodes. The

scatternet formation is achieved using the algorithm proposed in [9]. If more than one node is present in the communication range, nodes are allowed to form scatternets. Table I summarize the parameters used in this experiment.

TABEL I. SIMULATION SETTINGS

Parameters	Value
Total simulation time	28000s
No. of nodes	50
Area (range)	200x200m
Sub-Area (range)	30x30m
Transmit range	10 m
Node speed	1.5 m/s
Max. allowable slaves (per piconet)	07
Routing Protocol	AODV
Scheduling (or Polling) algorithm	PRR
Bridge Algorithm	TDRP
Packet Type	UDP
Packet Size	1400
Interval	0.015
Bluetooth Baseband packet type	DH5
Battery Life (initial)	10 J
Avg. energy consumption rate	2.5e-3 J
Min. Energy	0.1 J
Node Rank Recording (social popularity level)	Active
Probability of joining a group	0.5
Time to stay in a group	60-360s
No. of times each experiment run	30

B. Simple Movement Model(SMM)

The simulation world is divided into four groups and has 200x200m boundary range. In group ‘A’ nodes are allowed to move randomly whereas groups ‘B’, ‘C’ and ‘D’ represent meeting spots as shown in figure 3 and the boundary area of each group is 30x30m. Each node has 50% probability of joining any of these groups and node can stay in a given group between 60-360 seconds.

C. Results

Varying length of queue sizes are considered to measure the overall performance of algorithms. Queue size affects the overall performance of any routing algorithm, as this is natural that large queue size store more messages thus has less chance of message dropping. The algorithm performances are measured against three metrics: message delivery, communication cost and delays. Each of these

graphs show two curves which represent the behavior of BR and HCF algorithms. The X-axis of each graph represents varying queue sizes against which curves are plotted.

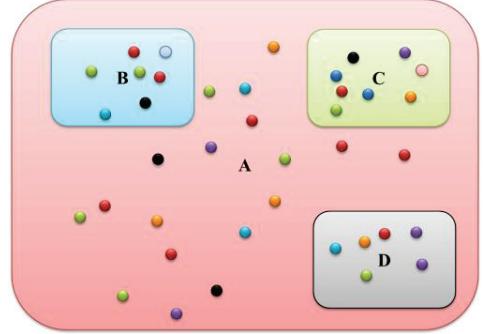


Figure 3. Simple movement model

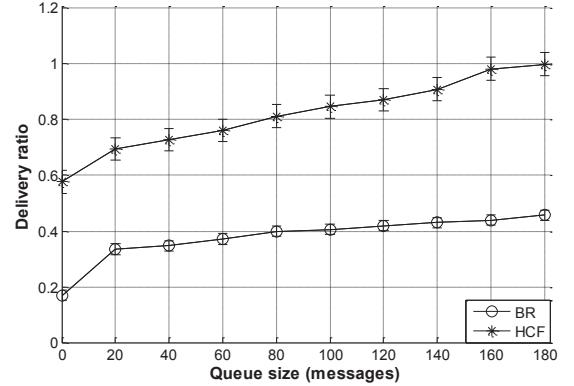


Figure 4. Average delivery ratio at destinations

Figure 4 shows the normalised number of messages received at destination nodes in simple movement model. HCF shows remarkable results compare to just BR technique in terms of message delivery. In BR, message forwarding takes place only when more popular nodes encounter, whereas, HCF successfully adapts according to the network conditions. When group of nodes are close enough such as in communication range, HCF form scatternets and AODV routing is used for communication. However, BR comes into play, when isolated nodes encounters or destination nodes are not present in the network. In the absence of destination node, source node locates the most popular node in the network using AODV. After locating the most popular node, source node starts message transfer to the most popular node using BR concept. When destination node joins the scatternet, source node stops message transfer to the most popular node, instead resume messages directly to the destination node. However, during the absence of destination node, the messages stored at the most popular node are now being retransmitted to the destination node. Graphs in figure 4 show that the observations based on which HCF adapts

network conditions are successful. This kind of hybrid approach indeed improves the overall message delivery ratio compare to just BR.

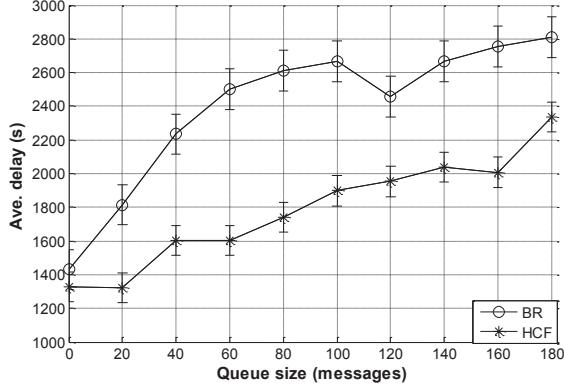


Figure 5. Average message delays

Figure 5 shows the average delays experienced during the message transfer from source nodes to intended destinations. HCF shows fewer delays compare to BR. In BR, nodes keep messages until find more popular nodes. Whereas, HCF adapts according to network conditions, if destination node is present anywhere in the scatternet, the source node or popular nodes can reach to the destination node via bridge nodes using AODV algorithm. AODV rely on shortest path, therefore instead of waiting for direct encounter as in BR, HCF reach to those nodes as well which are beyond its communication range. This kind of hybrid communication decreases overall message delays in the network.

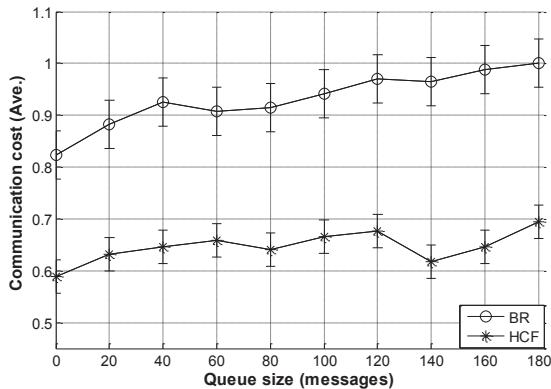


Figure 6. Overall network communication cost

Figure 6 shows the normalised communications cost of the network and plotted its average. BR proves to be costly compare to HCF. BR keeps on forwarding the message to more popular nodes until finds destination node or time to live of message expires. In HCF, nodes do not necessarily have to forward message to every popular node it encounter, instead in scatternet formation nodes can locate the most popular node in the network using shortest routes learn from

AODV algorithm and directly transmit messages to the popular nodes through bridge nodes.

VI. CONCLUSION & FUTURE WORK

It is quite evident from simulation results that the observations based on which hybrid content forwarding adapts network conditions turns out to be fruitful. HCF successfully forms scatternet formation when a set of nodes is present within range. It relies on opportunistic forwarding when one-to-one node encounter occurs. Use of MANETs protocols in combination of social forwarding algorithms certainly improves message delivery, delays and communication cost.

So far HCF is tested in synthetically design simple movement model in NS-2. To fully understand its performance, should be tested against different movement models and real world mobility traces and this would be the future course of direction. This kind of hybrid technique is very useful for environments where many nodes are present in a given area such as conference environment and can be used as cost effective communication for delay tolerant applications.

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