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Survey of Routing Techniques in Opportunistic Networks

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Abstract- Opportunistic networks are one of the most interesting evolutions of MANETs. In opportunistic networks, route connecting to the mobile nodes never exits, mobile nodes communicate with each other when they got opportunity to communicate. Furthermore, nodes are not supposed to possess or acquire any knowledge about the network topology. Routes are built dynamically, while messages are route between the source and the destination, and any possible node can opportunistically be used as next hop, provided it is likely to bring the message closer to the final destination. These requirements make opportunistic networks a challenging and promising research field.

Index Terms- Opportunistic networks, Routing, Multiple copy routing, Single copy routing

I. Introduction

In opportunistic networking no assumption is made on the existence of a complete path between two nodes wishing to communicate. Source and destination nodes might never be connected to the same network, at the same time. Nevertheless, opportunistic networking techniques allow such nodes to exchange messages between them. In this scenario messages may have to be buffered for a long time by intermediate nodes, and the mobility of those nodes must be exploited to bring messages closer to their destination by exchanging messages between nodes as they meet[1].

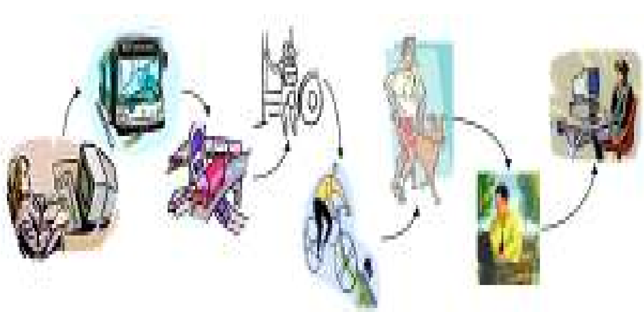

Fig. 1 Opportunistic networking [1].

For example, as is shown in Fig.1, the woman at the desktop opportunistically transfers, via a Wi-Fi link, a message for a friend to a bus crossing the area, "hoping" that the bus will carry the information closer to the destination. The bus moves through the traffic, then uses its Bluetooth radio to forward the message to the mobile phone of a girl that is getting off at one of the bus stops. The girl walks through a near park to reach the university. Her cellular phone sends the message to a cyclist passing by. By proceeding in the same way some hops further, the message eventually arrives at the receiver. As it is clearly shown in this example, a network connection between the two women never exists but, by opportunistically exploiting contacts among heterogeneous devices, the message is delivered hop-by-hop (hopefully) closer to the destination, and eventually to the destination itself.[1]

II. Routing Techniques in opportunistic networks

In opportunistic networks, network resources are constrained. For e.g. node depends on nodes battery power for its working, nodes are subjected to low memory space; also performance of these networks is depends on bandwidth of network. Routing is difficult in opportunistic networks because of no topology defined and frequent disconnections in nodes. In opportunistic networks design of efficient routing scheme is complicated task due to the absence of knowledge about the topology of the network. Routing performance improves when more knowledge about the expected topology of the network can be exploited [2]. Unfortunately, this kind of knowledge is not easily available, and a trade-off must be met between performance and knowledge requirement.

Fig. 2 shows the different routing algorithms in opportunistic networks. At the bottom of Fig.2 we list the examples of each class that we will mention in this paper.

A first classification is based on the number of copies of message are generates while forwarding. Algorithms in which network does not relays the message at all(*single copy based*), and algorithms in which network produces multiple nodes(*multiple copy based).*In the former case, multiple copy based approaches can be further divided in *broad cast based,* in which message floods in networks by each receiver, *history based* algorithms uses previous context information for taking forwarding decision , *network coding based* algorithms codes message before forwarding it *and ferrying based* algorithms relays message between intermediate nodes.

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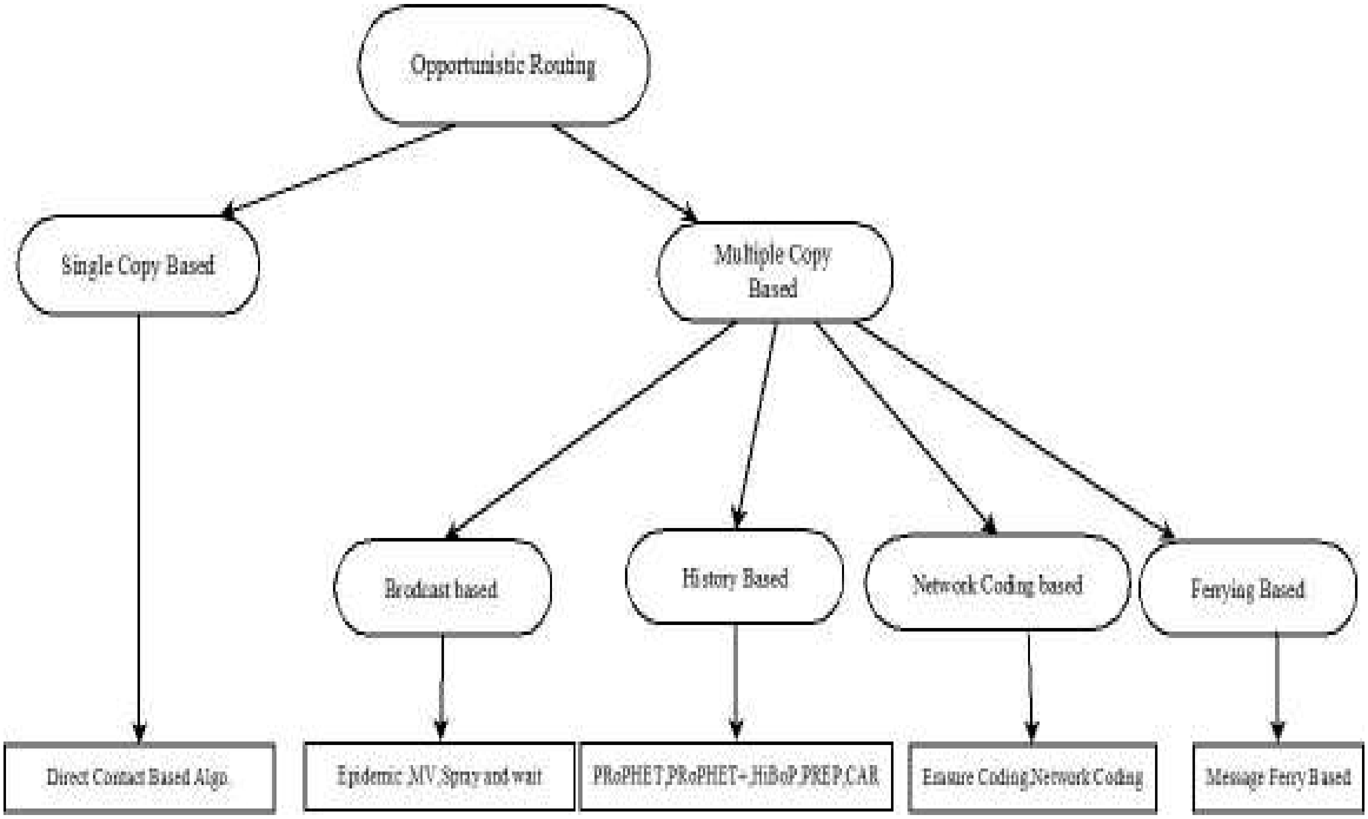

Fig.2 Routing in opportunistic network

III. Single-copy routing schemes

A. Direct contact based algorithm

Direct contact based algorithm was investigate the problem of efficient routing in intermittently connected mobile networks using single-copy approaches. Spyropoulos [4] proposed a simple single-copy routing called direct transmission routing. In this approach, after the source node generates a message, the message is hold by the source node until it reaches the destination node. The main advantage of this scheme is that it incurs minimum data transfers for message deliveries. On the other hand, although having minimal overhead, this scheme may incur very long delays for message delivery since the delivery delay for this scheme is unbounded [5].

IV. Multiple-copy routing schemes

A. Broadcast based algorithms

Routing techniques based on message Broadcasting perform delivery of a message to a destination by simply broadcasting it all over the network. This policy is used because, there is no knowledge of a possible path towards the destination nor of an appropriate next-hop node, should a message be sent everywhere. It will eventually reach the destination by passing node by node. Broadcast-based techniques obviously work well in highly mobile networks where contact opportunities, which are needed for data diffusion, are very common. They tend to limit the messages delay, but they are also very resource hungry. Due to the considerable number of transmissions involved, dissemination-based techniques suffer from high contention and may potentially lead to network congestion.

1. Epidemic routing

Epidemic Routing [6] relies on the theory of epidemic algorithms by doing pair-wise information of messages between nodes as they get contact with each other to eventually deliver messages to the destination. Nodes buffer messages when there is no available path to the destination. An index of these messages called a summary vector is kept by the nodes, and when two nodes meet they exchange them. So doing, each node can determine if the other node has some message that it did not see before and requests it. This means that, as long as there is some available buffer spaces, messages will spread epidemically as a disease, as nodes meet and "infect" each other. Besides the obvious fields of source and destination addresses, messages also contain a hop count field. This field is similar to the TTL field in IP packets and determines the maximum number of hops a message can be sent, and can be used to limit the resource utilization of the protocol.

2. MV routing

The routing protocol *MV* [7] maintains a movement model of the network participants and uses this information to perform routing of messages on the network. It estimates the probability of a particular message being delivered by a given peer, and thus is capable of making informed routing decisions.

The *MV routing* protocol is a further step beyond epidemic routing. Messages are exchanged during pair-wise contacts as in epidemic routing. However, the MV protocol introduces a more sophisticated method to select the messages to forward to an encountered node. Basically, the choice depends on the probability of encountered nodes to successfully deliver messages to their eventual destinations. The delivery probability relies on recent-past observations of both the *meetings* between nodes and the *visits* of nodes to geographical locations. The name *MV* protocol itself comes just from *Meetings* and *Visits*.

3. Spray and wait

Spray and Wait [8] bounds the total number of copies and transmissions per message without compromising performance. Under low load, Spray and Wait results in much fewer transmissions and comparable or smaller delays than flooding-based schemes, under high load, it yields significantly better delays and fewer transmissions than flooding-based schemes, and it is highly scalable, exhibiting good and predictable performance for a large range of network sizes, node densities and connectivity levels; what is more, as the size of the network and the number of nodes increase, the number of transmissions *per node* that Spray and Wait requires in order to achieve the same performance decreases, and it can be easily tuned online to achieve given QoS requirements, even in unknown networks.

b. History data based algorithms

Routing techniques based on history data are uses the information related to the nodes, like number of encounters with destination, movement pattern. These techniques reduce the number of messages forwarded in the network, and consume fewer resources than broadcast based algorithms.

1. HiBOp protocol

HiBOp [9] protocol is based on the concept of using context information for routing decision. Basically forwarding is based on the concept of opportunity to reach a certain destination, measured in term of probability of carrying the message closer to the destination. Messages are forwarded only to nodes with higher probability of getting them closer to the destination. The innovation of HiBOp is how context is exploited to evaluate these probabilities. The main idea behind this is that message sender includes more information about the destination than a simple network address. The sender should include (any subset of) the destination's Identity Table which includes information about the user itself. Delivery probabilities are evaluated based on the match between this information and the context stored at each encountered node High match means high similarity between the node's and the destination's context. Actually, delivery probabilities can be seen as a measure of this similarity. This technique is performs better than the Epidemic and PRoPHET in message delivery.

2. PROPHET

In the Probabilistic Routing Protocol using History of Encounters and Transitivity [10], the selection of the best neighbour node is based on how frequently a node encounters another. Prophet uses a probabilistic metric called *delivery predictability* that indicates how likely it is that *A* will meet *B*, and thus that will be able to deliver a message to *B*. When two nodes meet, they exchange their summary vectors, which contain their delivery predictability information. If two nodes do not meet for a while, the delivery predictability reduces. When the sender wants to send a message to the destination *D*, it will look for the neighbour node that has the highest amount of time encountering *D*, meaning that has the highest *delivery predictability* to *D.* This property is further transitive.

3. Context aware routing

In the *Context-Aware Routing (CAR)* protocol [11] each node in the network is in charge of producing its own delivery probabilities towards each known destination host. Delivery probabilities are exchanged periodically so that, eventually, each node can compute the best carrier for each destination node. The best carriers are computed based on the nodes' context. The context attributes needed to elect the best carrier are, for example, the residual battery level, the rate of change of connectivity, the probability of being within reach of the destination, the degree of mobility. When the best carrier receives a message for forwarding, it stores it in a local buffer and eventually forwards it to the destination node when met, or alternatively to another node with a higher delivery probability. CAR provides a framework for computing next hops in opportunistic networks based on the *multi-attribute utility theory* applied to generic context attributes.

C. Network coding based algorithms

The concept of network coding allows interior nodes of a network to not only forward but also to process information they receive.

1. Erasure based coding

Erasure codes [12] operate by converting a message into a larger set of code blocks such that any sufficiently large subset of the generated code blocks can be used to reconstruct the original message. The basic idea is to erasure code a message and distributes the generated code-blocks over a large number of relays. Instead of sending a full copy of the message over a relay, only a fraction of code-blocks are sent over each relay. This controls the routing overhead in terms of bytes transmitted, and the average delay can be reduced to a small constant. Erasure coding can also help to combat packet loss due to bad channel quality or packet drops due to congestion.

2. Network coding based

Network-coding-based routing [13] is similar to probabilistic routing but is based on network coding. Network coding is a relatively recent field in information theory. In contrast to simply forwarding the information contained in the packets, nodes may send out packets with linear combinations of previously received information.

Network-coding-based routing limits message flooding. Just to give a classical example, let A, B, and C, be the only three nodes of a small network. Let node A generate the information "a" and node C generate the information "c". Then suppose the information produced needs to be known at all the nodes. Hence, node A and node C send their information to node B. Then node B, rather than sending two different packets for "a" and "c", respectively, it broadcasts a single packet containing "a" xor "c". Once received "a" xor "c", both nodes A and C can finally infer the missing information (i.e., node A can infer "c" and node C can infer "a"). Network coding-based routing outperforms flooding, as it is able to deliver the same information with a fewer number of messages injected into the network.

D. Ferrying based algorithms

The Message Ferrying (MF) [14] scheme is a proactive approach for data delivery in sparse networks. It introduces non-randomness to node mobility and exploits such non-randomness to provide physical connectivity among nodes. In an MF scheme, the network devices are classified as message ferries or regular nodes based on their roles in communication. Ferries are devices which take responsibility of carrying messages among other nodes, while regular nodes are devices without such responsibility. There are many different ways to introduce non-randomness in node movement, as in the node-initiated MF scheme ferries move around the deployed area according to known routes, collect messages from regular nodes and deliver messages to their destinations or other ferries. With knowledge about ferry routes, nodes can adapt their trajectories to meet the ferries and transmit or receive messages. By using ferries as relays, nodes can communicate with distant nodes that are out of range.

V. Conclusion

Opportunistic network is an emerging technique getting growing interest in networking research community. The opportunistic network places different research challenges in this field. In this paper, we provide a quick overview of the routing schemes uses in opportunistic network for providing solutions to various issues in an opportunistic network. This work is aimed to serve as an introductory material to people who are interested in pursuing research in this area.

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