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Data Transfer Reliabilty and Congestion Control Strategies in Networks

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***Abstract*— Opportunistic networks are a class of mobile ad hoc networks (MANETs) where contacts between mobile nodes occur unpredictably and where a complete end-to-end path between Source and destination rarely exists at one time. Two important functions, traditionally provided by the transport layer, are ensuring the reliability of data transmission between source and destination, and ensuring that the network does not become congested with traffic. However, modified versions of TCP that have been proposed to support these functions in MANETs are ineffective in opportunistic networks. In addition, opportunistic networks require different approaches to those adopted in the more common intermittently connected networks, e.g. deep space networks. In this article we capture the state of the art of proposals for transfer reliability and storage congestion control strategies in opportunistic networks. We discuss potential mechanisms for transfer reliability service, i.e. hop-by-hop custody transfer and end-to-end return receipt. We also identify the requirements for storage congestion control and categories these issues based on the number of message copies distributed in the networks. For single-copy forwarding, storage congestion management and congestion avoidance mechanism are discussed. For multiple-copy forwarding, the principal storage congestion control mechanisms are replication management and drop policy. Finally, we identify open research issues in the field where future research could usefully be focused.**

Keywords-component; MANETs; end-to-end path; multiple-copy forwarding; hop-by-hop custody; replication management

I. INTRODUCTION

MOBILE ad hoc networks (MANETs) are infrastructure less networks where nodes can move freely. One node can directly communicate with another if they are within radio communication range. A node can simultaneously serve both as a source or destination of a message and as a relay for other messages. A message traverses the network by being relayed from one node to another node until it reaches its destination (multi-hop communication). Since the nodes are moving, the network topology regularly changes and so finding a delivery path to a destination is a challenging task. Constructing end to- end delivery paths and ensuring robust message delivery in the face of dynamic topology changes are challenges that have been addressed in MANETs, and an abundance of routing and transport protocols have been proposed.

In all these protocols, it is implicitly assumed that the network is continuously connected and that there exists at all times end-to-end paths between all source and destination pairs in the networks However, in some scenarios complete end-to-end paths rarely or never exist between sources and destinations within the MANET, due to high node mobility or low node density. These networks may experience frequent partitioning, with the disconnections lasting for long periods. As a consequence, the end-to-end transfer delays in these *intermittently connected networks* (ICNs) are much greater than typical IP data transfer delays in conventional networks such as the Internet.

In the literature, intermittently-connected networks are often referred to as *delay*- or *disruption tolerant networks* (DTN); however this term is more strictly associated with the Delay / Disruption Tolerant Networking architecture that is currently the subject of work within the IRTF DTN Research Group (DTNRG) [1]. Whilst research in ICN routing is now well established, research in ICN transfer reliability and congestion control is still in its early stages. So far, most of the work in these areas has been targeted at applications in deep space communications, for example the interplanetary Internet. Within ICNs we can identify opportunistic networks, which are networks where contacts between mobile nodes occur unpredictably because the node’s movement is effectively random, and where the duration of each node contact is also unpredictable.

The challenges of developing efficient algorithms for opportunistic networks are different from those of classic ICNs such as deep space networks. This article reviews transfer reliability and congestion control strategies in opportunistic networks. We initially consider ICNs in Section II, and review the DTN architecture, ICN routing strategies and transport protocols for ICNs. We then proceed to opportunistic networks in Section

III, where we consider how a network's characteristics affect its requirements for transfer reliability and congestion control. We then consider in detail proposals in the literature that address these subjects: in Section IV, we review strategies that have been proposed for message transfer reliability in opportunistic networks, and in Sections V and VI we review proposed strategies in congestion control for opportunistic networks. We categorize them based on the underlying forwarding strategy, i.e. single-copy (Section V) or multiple-copy (Section VI). Future research topics and challenges are discussed in Section VII. Finally, in Section VIII we conclude the article.

A. ICN Routing Strategies:

Routing in ICNs is more complicated than in MANETs due to the lack of up-to-date network topology information. Here we briefly review ICN routing strategies since, as we shall see, the routing algorithms affect design decisions about transfer and congestion control mechanisms. ICN routing protocols typically use historical node contact data to predict future network topology. Three categories of regularity of node contacts can be defined, namely on-demand contact, scheduled or predicted contact and opportunistic contact. We first divide the networks, based on node mobility, into static and mobile nodes. Static node networks can be either continuously connected (such as the Internet backbone) or intermittently connected.

The latter division includes wireless sensor networks (WSNs), whose nodes conserve energy by disabling their radio connection when not required. In the mobile node branch of the taxonomy, we again distinguish between networks where links between nodes generally exist and networks where node contact is intermittent. In MANETs, links are assumed to be always or usually available when needed; this is also known as on-demand contact. We use the regularity of node contact to further divide the intermittently connected mobile networks: we distinguish between networks where node contacts are predicted (e.g. the Interplanetary Internet (IPN)) or scheduled.

B. RELIABLE MESSAGE TRANSFER:

TCP is not able to provide efficient reliable end-to-end message transfer in ICNs. Other approaches have therefore been proposed. Four classes of reliable message transfer service in ICNs, namely custody transfer (CT), return receipt (RR), CT notification and bundle forwarding notification. Of these, we consider that CT and RR are more applicable in opportunistic networks. This is because the other strategies consume significant mobile node energy and network bandwidth by sending many more Ack signals to upstream relays and the source. In CT, a custodian node takes responsibility for retransmission so the source can release its buffer quickly without waiting for an Ack to arrive from the destination. However, CT cannot provide a fully reliable data transfer service since if a custodian node fails it is unable to notify the source. On the other hand, in RR an end-to-end Ack is sent back to the source confirming that a message has been received by the destination. RR is therefore able to provide a fully end-to-end reliable service, but at the cost of using the source's storage space, which has to retain unacknowledged messages, potentially for a long time.

C. CONGESTION CONTROL (SINGLE-COPY CASE):

In a single-copy forwarding strategy, every time a node successfully forwards a message to the next relay node or the destination, the forwarding node deletes the message in its storage. Thus, at any instant only one copy of the message exists in the network. Congestion that forces a node to drop a message in the buffer will significantly degrade the network's delivery ratio since there are no other copies of the message in the network and no mechanism exists to inform the source in a timely fashion that it should retransmit the dropped message. Hence, storage congestion management mechanisms are required at the receiving nodes and congestion avoidance mechanisms are required at the forwarding nodes. Together, these enable nodes to offer a safe and efficient message custody service. We now discuss storage congestion management and congestion avoidance approaches described in the literature.

II. PROBLEM APPROACH

Existing storage congestion management proposals can be divided into two categories:

Those that use economic models to determine whether custody of a message should be transferred to a new node, And those that analysis of network traffic levels to make this decision. One drawback of the greedy scheme is that it does not consider the cooperation between the neighboring nodes. So the greedy Scheme performance may be limited.

we propose two important functions, traditionally provided by the transport layer, are ensuring the reliability of data transmission between source and destination, and ensuring that the network does not become congested with traffic. However, modified versions of TCP that have been proposed to support these functions in MANETs are ineffective in opportunistic networks. In addition, opportunistic networks require different approaches to those adopted in the more common intermittently connected networks, e.g. deep space networks. In this article we capture the state of the art of proposals for transfer reliability and storage congestion control strategies in opportunistic networks. We discuss potential mechanisms for transfer reliability service, i.e. hop-by-hop custody transfer and end-to-end return receipt.

We have reviewed and discussed proposals for transfer reliability and storage congestion control in opportunistic networks. We provide a summary of the congestion control strategies in Table I. This table includes the service target of each strategy, giving the principal delivery objective as either maximum delivery ratio or minimum delivery delay or both. The authors of some papers clearly state the service target of their proposal, whereas other authors use the delivery ratio and/or delivery delay as metric(s) to measure the proposal's performance in computer simulations or mathematical models. ICNs do not satisfy traditional networking assumptions, where end-to-end paths always exist, and the networks have low propagation delays or round-trip times, low bit error rates, and high bandwidth. As a result, communication protocols built for these conventional networks, e.g. the Internet and MANETs,

Data Replication:

Data replication has been extensively studied in the Web environment and distributed database systems. However, most of them either do not consider the storage constraint or ignore the link failure issue.

Before addressing these issues by proposing new data replication schemes, we first introduce our system model. In a MANET, mobile nodes collaboratively share data. Multiple nodes exist in the network and they send query requests to other nodes for some specified data items.

Each node creates replicas of the data items and maintains the replicas in its memory (or disk) space. During data replication, there is no central server that determines the allocation of replicas, and mobile nodes determine the data allocation in a distributed manner.

The One-To-One Optimization (OTOO) Scheme:

It considers the access frequency from a neighboring node to improve data availability.

It considers the data size. If other criteria are the same, the data item with smaller size is given higher priority for replicating because this can improve the performance while reducing memory space.

It gives high priority to local data access, and hence the interested data should be replicated locally to improve data availability and reduce query delay.

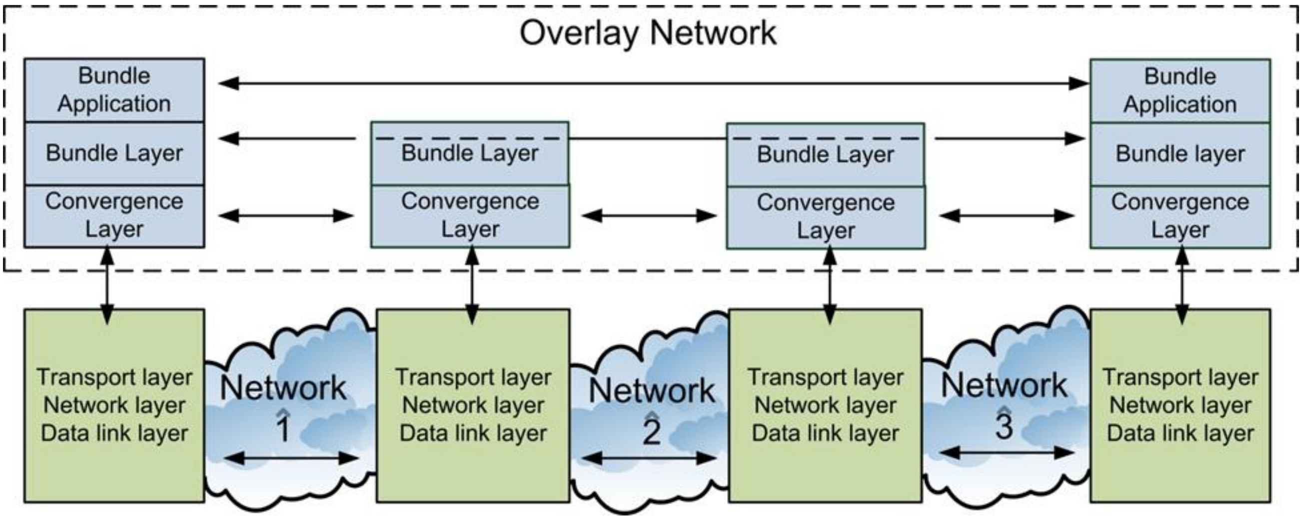
It considers the impact of data availability from the neighboring node and link quality. Thus, if the links between two neighboring nodes are stable, they can have more cooperation's in data replication.

The Reliable Neighbor (RN) Scheme:

OTOO considers neighboring nodes when making data replication choices. However, it still considers its own access frequency as the most important factor because the access frequency from a neighboring node is reduced by a factor of the link failure probability.

To further increase the degree of cooperation, we propose the Reliable Neighbor (RN) scheme which contributes more memory to replicate data for neighboring nodes. In this scheme, part of the node's memory is used to hold data for its *Reliable Neighbors*. If links are not stable, data on neighboring nodes have low availability and may incur high query delay.

Thus, cooperation in this case cannot improve data availability and nodes should be more "selfish" in order to achieve better performance.



Reliable Grouping (RG) Scheme:

OTOO only considers one neighboring node when making data replication decisions. RN further considers all one-hop neighbors. However, the cooperation's in both OTOO and RN are not fully exploited.

To further increase the degree of cooperation, we propose the reliable grouping (RG) scheme which shares Replicas in large and reliable groups of nodes, whereas OTOO and RN only share replicas among neighboring nodes.

The basic idea of the RG scheme is that it always picks the most suitable data items to replicate on the most suitable nodes in the group to maximize the data availability and minimize the data access delay within the group.

The RG scheme can reduce the number of hops that the data need to be transferred to serve the query.

III. CONCLUSION

The nature of opportunistic networks means that some conventional end-to-end transport functions have to be additionally supported within the network. In particular, transfer reliability and congestion control mechanisms have to be implemented in the network on a per-hop basis, and traditional fixed network functions, such as packet forwarding and dropping and congestion control, become more tightly coupled. In this article we have provided an overview of the state of the art of proposals for transfer reliability and congestion control in opportunistic networks. We have described existing proposals for opportunistic network transfer reliability in Section IV. We have discussed congestion control approaches, based on the network's replication strategy, whether single-copy (Section V) or multiple-copy strategies (Section VI). The main contributions of this article are Considering transfer reliability and congestion control proposals taking account of opportunistic networks' characteristics;Identifying open research issues in transfer reliability and congestion control in opportunistic networks. We hope the article enables readers to have a better understanding of the current state of the evolving research. Unlike ICN routing, research in these areas is still in its early stages and there are many open issues that need to be addressed before the benefits of opportunistic networks can be fully realised. Finally, it is our intention that the article provide better insight into the importance of transfer reliability and congestion control functions in supporting the message delivery service, whether that be focused on high message delivery ratio or low delivery latency.

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