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AN OVERVIEW OF DELAY TOLERANT NETWORKS AND ROUTING PROTOCOLS

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Abstract

Deep space networks, satellite networks and mobile devices networks can be modeled as Delay Tolerant Networks (DTNs). The introduction of this article comes with a global view over this type of network. The literature review section identifies some challenges met by this type of network and one of the most important evaluation criteria for a DTN. Not only the physical resources, but the routing algorithms that must work with resources and capabilities that are not found in a traditional network contribute to the performance of a Delay Tolerant Network. This aspect is touched in the personal remarks section of the article.

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1 Introduction

Nowadays we use networks in almost every domain. One of the most used networks is the Internet, which contains smaller networks with different communication protocols. The most used Internet protocols is TCP/IP. In addition to wired networks, there are also wireless networks. In the second category there are Mobile Ad Hoc Networks (MANETs) where two network devices connect if they are in the connection range of one another. Links between network connected devices may have periods in which they are active and periods when they are inactive. The activity intervals are influenced by the limited energy resources of the devices or by their high mobility [1]. To deal with such challenges and

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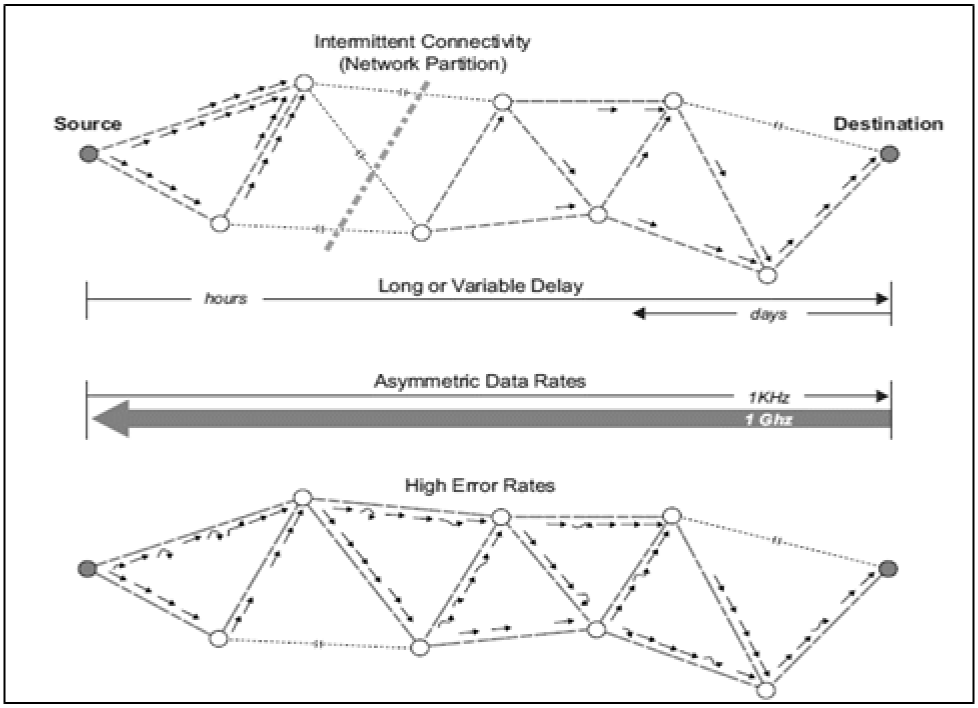

Figure 1: DTN environment characterization [1]

limitations provided by network to communication protocols, another overlay network over MANETs has been developed. This type of network provides a powerful enough mechanism for storing data packets over a long period of time and redirecting them after re-establishing the connection [2, 3]. This overlapping network tolerates long links disconnections and very long data transmission delays. Networks of this type are called DTNs (Delay and Disruption Tolerant Networks), and their architecture is proposed by S. Burleigh & Co's articles in [2, 3].

According to [4], a DTN is a network that can connect devices and area on the earth that cannot be served by a traditional network. This is due to the fact that there can be no continuous communication between the end points of communication (the source and the destination of the message). However, in order to make communication possible, the intermediate nodes must take over the custody of the transferred data and pass it on as soon as an opportunity arises. Both nodes and links between them are unsafe in a DTN, and disconnections can be long. A critical challenge for DTN networks is the determination of the transfer route of the message without ever having a previously established connection from the source node to the destination node.

According to its specifications, there are many applications for Delay Tolerant Network: wireless communication and monitoring, cargo tracking, agricultural crop monitoring, security and disaster communication, global airport traffic control, infrastructure integrity monitoring, animal migration, atmospheric and oceanographic conditions, unmanned undersea vehicles, oil and mining underground sensors, etc. DTN could also be used to receive data from everything ranging from sensors in oceans, to satellites in space.

2 Literature review

Delay Tolerant Networks are subject to challenges that are not present in traditional networks. These challenges come from the need to deal with the network interruptions that influence the routing and sending of the messages. Since this type of network connects various types of devices, there are many issues that routing mechanism should know and manage.

In [4], Evan Jones has identified the following challenges:

- Contact schedule is one of the most important features of a DTN because one of the most significant factors is the waiting time of a node until it comes in contact with another node. This factor may vary from seconds to days and schedules can have variable precision.
- Links capacity refers to the amount of data that can be exchanged between nodes. This depends both on the technology used for connection and on the duration of the connection. Even if the duration of the connection is known, it may not be possible to predict the amount of transferred data due to transmission fluctuations.
- Buffer size is an important factor in DTN because, due to long network disconnections, the messages have to be stored in node buffers for a long time. This means that intermediate routers need to have buffers with enough space to store all the messages that are waiting for communication opportunities.
- Processing power is another important factor in DTN because they connect various types of devices that cannot serve a traditional network. Such devices can have a very small dimension and, implicitly, a small processing capacity due to the processor and the memory. These nodes will not be able to run complex routing protocols.
- Energy power some nodes in DTN have limited power resources because they are mobile or because they are in a location without easy access to the power grid. The routing process consumes energy when sending, receiving or storing messages and that is why energy power is a crucial factor.

Routing protocols refers to the communication modality between routers for distributing messages through a network from the source node to the destination node. Routing algorithms determine a specific route between two nodes.

In [5] we can find DTN routing protocols divided into two major categories: forward based protocols and flooding based protocols.

Forward based protocols will keep a single copy of each message. This category is divided into three subcategories: infrastructure-based strategies, prediction-based strategies and social strategies.

The infrastructure-based approach is defined by:

- the existence of mobile agents, that will handle the transmission of messages where there are network disconnections
- the prediction-based approach, that uses historical knowledge to predict the motion of the nodes
- the social approach, that is based on knowing the social behavior of the network nodes and applying this knowledge to anticipate future changes.

Flooding based protocols have an opposite approach because they multiply the messages to spread them into the network. This category is divided into subcategories too: spray based, social based and coding based.

The spray-based approach applies a two-phase algorithm: a spraying phase that sends a number of copies of the message and a queuing phase where the nodes use the direct delivery. The social approach of the flood-based protocol is similar to the social approach of the previous protocol, but this time multiple copies of the message are created to increase the likelihood that messages will be delivered. The coding approach divides messages into smaller fragments, floods the network with them, and then nodes will be charged with the recombination and forwarding of these fragments. Once all the fragments have arrived at the destination, they are decoded and the original message is reassembled.

In order to compare routing strategies, certain performance criteria must be established. In [4] we find three such criteria: delivery rate, transmission and latency.

Delivery rate is an important evaluation criteria because a DTN cannot send a message for a long period of time because of the frequent network disconnections.

Some routing strategies send more messages than others, whether they use multiple copies of the same message or make different choices on setting up the next hop, or because they are using more complex processing. The number of messages transmitted is an important evaluation criteria of a DTN since each message has certain processing needs, but also a measure of energy consumption because each message transmission consumes energy.

Latency is defined by the time period between the moment the message is generated and the moment it is received by the destination. This criterion is important because many applications can benefit from a short waiting time, even if they are able to tolerate long waiting times.

3 Personal remarks

DTN networks are increasingly used because nowadays contexts are such that a traditional network can hardly cope. It uses sensor networks to measure various meteorological phenomena, satellite network in space (moving between various celestial bodies), networks that contain various mobile devices with a height range of mobility that cannot always be in the signal coverage area. Considering these aspects, it is understandable that the resources used by such a network, which must operate under extreme conditions, are limited.

For example, signal transmitters and signal interception devices in the study of behavior and lifestyle of wild animals with a very high degree of movement can often come out of the coverage range or may remain free of electricity for quite long periods of time. For this reason, the buffer space must be quite large, as important information can be recorded when the data capture devices are out of the network coverage area.

Also, routing algorithms need to be developed to take account of the limitations imposed by such a network. If it is known that network nodes have a large storage capacity and the bandwidth can handle the frequency with which messages are transmitted, a routing strategy based on the scattering of multiple copies of the message in the network can be used, for increasing the chance that the message will reach the destination (for example, the database of the stored information in the field). On the other hand, if the nodes meeting schedule is known or the frequency with which the source node meets the destination node is high, then a routing strategy based on the direct packet data transmission can be used, because it is a strategy with a fairly low cost in order to use only one copy of the message being transmitted.

However, it is difficult to compare two routing algorithms, since they were designed to serve different situations.

For example, in a satellite space network, given that their movement is based on a well-established timetable, it can pretty well approximate the moment when two satellites can come into contact with each other. In such situations, a PRoPHET routing algorithm (Probabilistic Routing Protocol using History of Encounters and Transitivity) can be used. This protocol uses an algorithm that attempts to exploit the non-randomness of real-world encounters by maintaining a set of probabilities for successful delivery to familiar destinations in the DTN. This approach was first addressed in [7].

On the other hand, if we have a sensor network that monitors the migration of wild animals, entering the range of action of the sensor from which data is captured cannot be made according to a timetable. In this case, a more appropriate approach would be to use a Spray and Wait routing algorithm. When the monitored animals pass near a device that can capture information, the data packet is transmitted to this device. The device waits until it encounters the destination node or an intermediate node with the ability to transport the message to the destination.

Anyway, if it were to give priority to DTN performance criteria, routing protocols should give the highest priority to the message delivery rate, then the message transmission mode, and barely the third value to the delivery delay. It is less important that the algorithm contains a fast delivery strategy if the message delivery rate is low or if the network and buffer loading is so high that the messages are dropped and probably the number of messages that succeed in reaching the destination decreases.

One of the points of view regarding the storage capacity of the nodes would be that the routers must have buffer space compared to the message storage request. Another point of view would be that routing strategies should take into account the available buffering capacity when deciding to send a message. Each one comes with its advantages and disadvantages. The first point of view has the advantage that the routing protocol does not require too much processing to identify network traffic when a packet is to be transmitted. By reducing the number and type of processing, both power and device memory consumption will be reduced. The disadvantage is that not all the devices are capable of holding large buffers. The second point of view increases the complexity of the routing algorithm, but it can work quite well with devices with low storage capacity.

4 Conclusions

Many existing or potential communication media are not in line with the fundamental assumptions of the Internet network, which must have a continuous and bidirectional connection between the data source and their destination, low network delays (in the order of milliseconds), symmetric and consistent data transfer rates between the source and the destination and low loss or corruptions of the data. According to [6], these environments are characterized by: intermittent connection, long delays and delay values that can vary consistently in the transmission of messages, asymmetric message transfer rates with a fairly high asymmetry which is unacceptable for the Internet communication protocols and high rate of errors during links. Corrupting bites on links involves correcting them, which implies more processing or even the retransmission of the whole packet, resulting in more network traffic. DTN routing protocols may take into account the constraints of this kind of network.

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