2014 IFIP Wireless Days (WD)

FREAK DTN: Frequency Routing, Encounters And Keenness for DTN

Patrice Raveneau , Emmanuel Chaput , Riadh Dhaou and André-Luc Beylot
Université de Toulouse - IRIT - ENSEEIHT Email: {patrice.raveneau, chaput, dhaou, beylot}@enseeiht.fr

***Abstract*—Mobile systems monitoring is an application area for Mobile Wireless Sensor Networks (MWSN), which introduces some specific challenges. Delay/Disruption architecture tackles some of these issues, such as delay and connectivity disruptions, and thus has already been used in this context. However, WSN nodes have severe limitations, concerning storage and processing capabilities. This performance problem has not been investigated as it deserves and this is the purpose of this paper. We propose the FREAK scheme which aims at reducing the computation while performance remains high. This scheme relies on the mean frequency of past encounter with the base station. Transmissions are driven by this metric. The FREAK solution is keen because we assume that future can be predicted from the past events. We also analyse the acknowledgements effects on performance. Our proposition is evaluated through simulations based on real traces. FREAK is compared to several replication and quota-based mainstream DTN solutions and achieves quite better performance in realistic scenarios.**

Keywords*—*Wireless Sensor Networks, Disruption Tolerant Networking, Scheduling

I. Introduction

The interest for tracking animals [1] and the concept of Internet Of Things [2] are two examples of the strong need in wide area data gathering applications. Monitoring systems use a wide range of technologies; from Wireless Sensor Networks (WSN) to Unmanned Air Vehicles (UAV) and observation satellites. These scenarios range from population tracking to temperature monitoring.

Mobile sensing nodes are required by some monitoring applications such as wildlife tracking, health monitoring or military applications. In Mobile Wireless Sensor Networks (MWSN), most nodes are small devices with very limited memory and few computation skills. These limitations require adapted solutions and present a real challenge.

The connectivity of a mobile network cannot be maintained for long periods. Schemes and protocols handling long link disruptions are compulsory for this type of scenario. The Delay/Disruption Tolerant Networking (DTN) architecture is appropriate to the described context. Indeed, the nodes carry data for a potentially long-term period data, either generated locally or by other nodes. This is the purpose of the Bundle Protocol [3].

In MWSN, the collector node or base station is static most of the time. This node shall also implement the Bundle Protocol. The base station will get Bundles (Bundle Protocol Data Units) from any node in the network.

In a mobile monitoring scenario, the future may be predicted thanks to the past rate of encounters. This assumption is made in some DTN opportunistic scenarios. For our purpose, the constraints are the low memory amount and the weak computation skills of devices. We focus on a population monitoring scenario.

The FREAK solution that we propose is based on frequency of encounters with the destination. We assume that for such scenarios, with limited memory devices, the information on the encounters with the destination is enough to make decisions for forwarding Bundles.

We first analyse the results of MWSN and social networks then present our contributions and finally discuss the latter.

II. Related Work

Several studies focus on DTN and WSN [4]–[7]. The sparseness of some MWSN does not allow to use standard WSN protocols. In these conditions, DTN protocols could be integrated to a MWSN scenario.

Since DTN can handle long link disruptions, it could be adapted for scenarios with static nodes prone to failures. Parts of the network may remain active while the whole network may be disconnected. However, low memory devices may not be able to handle long disruptions. A more representative scenario for DTN is the health monitoring scenario, such as defined in [8], which is presented for an analysis of single-copy routing protocols. In this scenario, the path existence is assumed to be known. The trouble comes from the disconnections between nodes. Nevertheless, in this scenario the disruption duration is far shorter than data lifetime. In a more general mobile context this assumption is no longer valid. Then replication [9], [10] or quota-based [11] solutions are more suitable.

In order to limit the flooding while keeping a good delivery ratio, the transmission of a replica is conditionned by the use of a metric. In [12], when nodes meet each other, they transmit replicas based on their past encounters. This method takes into account the whole encounter number of a node. In a wildlife tracking system, this metric is not useful as animals might stay in groups. Replicating data within a group does not necessarily increase the delivery ratio.

Finally, standard replica-based DTN protocols provide useful metrics but require too much memory and computation skills. For MWSN applications, a simple nodes classification could be based on similar metrics of other well-known DTN solutions.

Our proposition named FREAK (Frequency Routing, Encounters And Keenness) relies on the principle that *the future rate of node encounters can be roughly predicted by past data*.

This assumption presented in [12] is keen. Furthermore, our proposition takes into account the frequency of contacts only with the destination rather than considering the number of encounters with all other nodes. The restriction to the destination allows to fit the memory limitations and computation constraints. Moreover in many real scenarios, the assumption is reasonable. Indeed, animals or humans spend their time close to a home. Since they do not live in the same place, some representatives of the monitored species are more likely to meet a static position than others. Furthermore, in the context of the studied scenarios, we cannot be sure that each node will provide its data to the destination. Then if we want to get deliveries from most of the nodes, we might increase the delay to improve the delivery ratio. Nevertheless, the more our assumption is valid and the least the delay will increase.

III. How FREAK is conceived ?

The scenario we focused on for this study concerns population monitoring. This type of scenario suits a wide variety of applications such as wildlife tracking, healthcare monitoring or environment analysis thanks to UAVs. This study is a continuation of an earlier proposed solution that retrieves data from sensor networks in hostile environments thanks to satellites or other mobile nodes [13]. If the Bundle Protocol is implemented on all nodes of an architecture, such as the one presented in [14], then the sensors are not limited by the use of a single base station. An end-to-end naming scheme could be proposed and would make relaying easier.

The traffic generated by the sensors is supposed to be periodic and to represent a small data volume. Since sensors do not have a lot of memory, their buffer contains very few places. We use several mobility scenarios, either from traces or from mobility models. Even if this is not exhaustive, the exploration of different mobility patterns aims to analyse how the protocols perform in various mobility scenarios.

The base station is static while other nodes are moving. We compare our solution to the main DTN protocols which are Epidemic, Prophet and MaxProp. We analyse the effects of the use of acknowledgements (ACKs) on the network performance. We modify the size of buffers in order to see the influence of buffers size on the network performance and the protocols behaviour. We consider Bundles lifetime infinite. The analysis depends only on data inter-arrival rate, inter-contact durations and memory nodes capacity.

We could think that, in a low-memory scenario, replication or quota-based protocols might not be the best solutions to improve network performance. However, if we do not take benefits from the contacts, nodes experience; then we waste time and resource. A tradeoff has to be found between the number of replicas and the resource use efficiency. A metric based on the encounters, such as the one of Encounter-Based Routing (EBR) [12] , seems useful.

Our main assumption is that some nodes will meet the base station more often than others. Their inter-contact duration may also be smaller than other nodes. Rather than determining the number of encounters with all nodes, we compute the mean frequency of encounters with the base station. The best relays are the ones getting in touch with the base stations several times with a high frequency.

The higher the mean frequency of encounters with the base station the better. Then the mechanism to replicate a Bundle is simple. If a node meets another node with a higher value for the metric than itself, replicas are sent otherwise this node receives replicas from the other node. The algorithm 1 presents how works a node implementing FREAK.

Algorithm 1 FREAK Scheme

```
Let A be the local node
nbrContacts = 0
freq = 0
if B is the destination then
    nbrContacts++
    freq = nbrContacts/CurrentTime
    Send all Bundles
    Remove all delivered Bundles
else
    if contact_freq(A) < contact_freq(B) then
        Send all Bundles
    else
        Wait for Bundles
    end if
end if
```

IV. Simulations

A. Simulated environment

In order to validate the FREAK proposal, we simulate the behaviour of the network thanks to "The One" simulator [15].

The performance metrics that we analyse are the delivery ratio, the delay and the overhead. The overhead is defined as the ratio between the number of transmitted Bundles and the number of received Bundles. The objective is to send the maximum data amount to the destination, as fast as possible at the lowest cost.

We use the real traces collected from the San Francisco cabs [16]. During the simulations, each node generates data periodically. Table I summarises the parameters for the simulations.

B. Results interpretation

The results from the real traces show that FREAK provides a slightly better delivery ratio than other protocols. The delay is the worst metric for our proposition but as far as the monitoring data reaches the destination, no matter how long it takes. If it took too long the Bundles would be discarded from the network. Nevertheless, the overhead is close to other solutions. FREAK is, in most cases, the second behind Prophet in terms of overhead.

FREAK provides for real-traces scenarios a better delivery ratio than the three reference DTN protocols. Even if the overhead is in the same range as the overheads of standard DTN protocols, these performance are achieved while the complexity in terms of memory and computation does not depend

Table I. Summarised Simulations Parameters

Number of nodes	539
Mobility Traces	Taxi San Francisco (SF)
Simulation Duration	1 - 3 days
Buffers size	[1 - 6] Bundles
Data inter-arrival period	1600 s

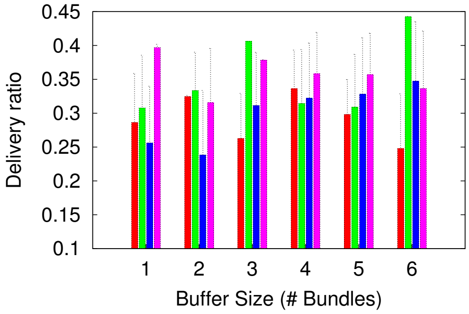

Figure 1. Delivery for SF cabs with limited Ack

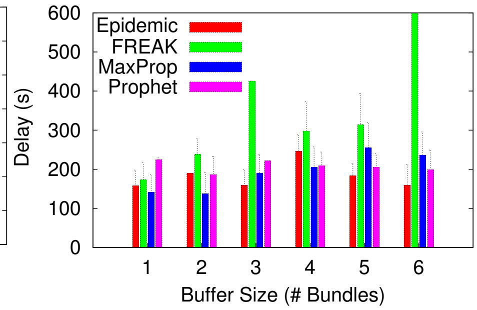

Figure 2. Delay for SF cabs with limited Ack

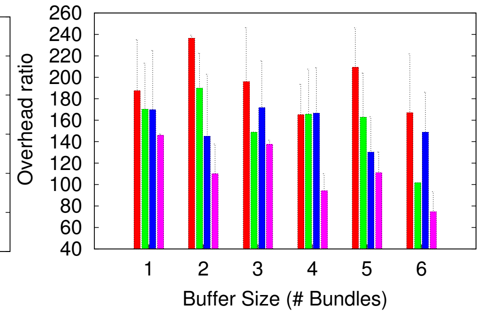

Figure 3. Overhead for SF cabs with limited Ack

on the number of nodes nor Bundles. Then, this mechanism is scalable and meets its purpose of keeping computation costs low while providing the same performance of delivery than the reference DTN protocols. These protocols are too heavy to be implemented on small devices with low memory capacity. Moreover, the FREAK scheme provides for scenarios based on real traces better delivery performance while the delay is in the same range as other protocols. It appears that the assumption is valid for real scenarios and that our proposition using less computation and memory than reference DTN protocols achieves better performance.

V. Conclusions

We propose the FREAK scheme, aiming at providing low computation cost while providing better performance than reference DTN protocols. We analysed our proposition and compared it to several DTN protocols thanks to simulations. These simulations were run with real traces.

Our proposition provides performance in the same range as DTN reference one, by assuming that past events influence the future ones. This assumption is widely used in DTN unless for some protocols such as Epidemic, which is very resource consuming. We also note that the longer the scenario lasts the better our proposition works.

As a perspective of this work, we are currently implementing FREAK on MicaZ devices with a lightweight version of the Bundle Protocol that we also implemented on these motes. Since on these motes there is not enough hard memory to implement a protocol such as MaxProp or Prophet, the fact that our proposition, which is small enough to fit in these sensors, provides better performance than standard DTN protocols is hopeful. In addition, the management of acknowledgements deserves further study. Indeed, in a context where the memory is the strongest constraint, and that this mechanism can reduce losses, we must analyse if an optimal compromise can be determined. Then if an overload occurs, the best decision is made between removal of acknowledgements or Bundles.

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