An Effective Architecture for Reliable Communications in VDTN

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Abstract

Custody transfer method is often managed by the general architecture of Delay Tolerant Network (DTN) to provide reliability in the communications through storage and forward paradigm, but can be inefficient when the acknowledgment messages are lost, or the network becomes congested. In this paper we describe a new architecture that is particularly efficient for the custody transfer method. Because, it provides an additional control of acknowledgment messages, consolidate knowledge and services, using the advantage of the cross-over architectures and distribution control through local and global services.

1. Introduction

The vehicular network is an important emerging technology for the future use of internet. However nowadays one of the most prominent problems being faced by the vehicular networks is the reliability among communications, due to the heterogeneous nature and mobility of the environment.

The end-to-end scheme guarantees the reliability of communications through *acknowledgment messages*, but when mobility or disconnections appear this method does not ensure it; then, instead of this, the hop by hop reliability and custody transfer are implemented. Nevertheless, problems related to the *CAP theorem* [5], which be established that no network can be simultaneously consistent, available and tolerant to partitions, come into sight.

Some *delay tolerant network* approaches manages the reliability communications problems in several proposals, such as, *DTN: An Architectural Retrospective* [2], explains that DTN allows the set of potential custodians to be configured. *The Store-and-Forward Performance in a DTN* [3], expounds the custody transfer process to vouch for the reliability during communications. So far, the currently provided reliability is not sufficient. Therefore, we propose a new DTN architecture to enhance the reliable in communications within vehicular networks.

Hence the proposed architecture is designed to solve these problems in a clever and proficient way including a *DTN repository,* which operates as a knowledge repository to be accessed by some network layers (as, bundle, transport and network layer). The *knowledge repository* manages the information of acknowledgement messages efficiently; as a consequence it improves the reliability among communications, making the vehicular networks more accurate and skillful.

The rest of the paper is structured as follows. Section 2 gives an overview of the approaches related to the reliability problem within a tolerant disconnection environment. In section 3 we explain the *Layered Architecture* and study its principal components. In section 4, the performance and behavior of the solution using an application scenario is illustrated. Section 5 the Performance & Evaluation of the proposal. Finally, section 6 concludes the paper.

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2. Related Work

Research on DTN has been working to get better reliability: *DTN: An Architectural Retrospective* [2], considers that intermediate nodes can be more reliable and have better connectivity than end nodes. However, a node may refuse to accept custody for messages, because of implementation, policy reasons, congestion or other situations. Thus, it could affect the reliability.

EDIFY architecture [3] implements custody transfer to provide reliability, which illustrates the usefulness of the custody transfer feature and the message ferry to improve the end-to-end message delivery ratio, they also recognize the need to design a more intelligent distributed buffer management to achieve high delivery ratio for DTN environments.

Custody Transfer for Reliable Delivery in Delay tolerant Networks [6] presents the problems that arise with the existing strategies to address the reliability through custody transfer mechanism, and analyzes the relation between Availability vs. Consistency. They propose the concept of *joint custody* to mark messages that may have been duplicated. Nevertheless, this method does not solve or prevent the problem; it only makes the inconsistencies detection easier.

Thus it is essential a suitable solution to assure the reliability of communications when the disconnection appears. To overcome this challenge we propose a new architecture, which controls the availability and consistency at the same time.

3. Layered Architecture

a. Motivation of the Architecture

The custody transfer is used by most of the proposals that implement delay tolerance. Though, it has some problems such as: consider custody transfer like a transaction because when the disconnections appear it is better to have control of each completed task [6]; or the rise of duplicates, considering the availability vs. consistency, because it is possible that two custodians nodes are responsible for the same message (joint custody), then, availability is warranted but on the other side the consistency is not given, as consequence some in-work operations might produce incorrect answer. To solve this complex problem we propose a distributed and automatic control to maintain the availability and consistency of the data transmissions and to administer the information of acknowledgment messages efficiently within vehicular network, consequently it is required define a new architecture to be made possible this control and ensure a higher reliability and optimization of communications in vehicular networks. Next it is specified the components and features of the Architecture.

b. Overview of the Architecture

We follow the general architecture of the DTN approach, but we also include a new component called "*DTN repository*", with the principal functions of: 1) providing a local and global control of the communications between the protocols in a disconnection scenario, and 2) the reduction of inconsistency problems taking control of the custodian's acknowledges. We take advantage of the wired networks to give a global control as it is being used in the proposal *An intelligent infotainment dissemination scheme for heterogeneous vehicular network* [1], where is proposed a service-oriented information dissemination scheme to ensure the possibility of heterogeneous vehicular communication.
The communication between the *DTN repository* and the rest of the layer is similar to the cross-layer interactions.
The principal components of *DTN repository* are illustrated in the figure 1. The blue components are the interfaces that provide the services to the others layers. The "Service Interface" component supplies the services of all the available functionalities inside the "Application" component. The "Data access" component confers services related to data base, such as, records, queries, etc.
The "Application" component has all the software that assures a good control of the custodians and the messages inside the network at a specific time, for example select the best custodian to a specific message, through an algorithm. This component has other two important elements: "parameters" and "feedback", these guarantees a good services in real –time.
The "Data" component has the task of handling all the information saved in the data base. It contains two elements aimed to provide better control of the principal task; these elements are "configurations" and "updates", these have procedures previously optimized to administer the update and configuration processes in an easier way.
The DTN application works in object-oriented scheme, using metadata and XML for the interactions between interfaces.

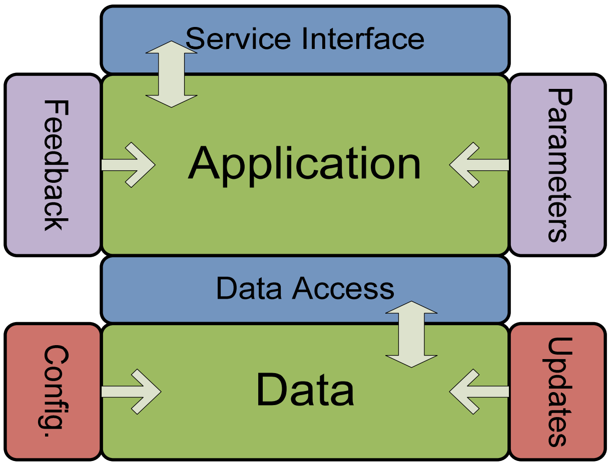

Figure 1. Components of DTN repository

c. Interactions between Protocol Layers and the DTN repository

The basic architecture of the DTN approach includes the *Bundle layer* that enables the heterogeneous communications, the identification of the regions, storing and forwarding the data among other features. With the *DTN repository* component other features are added, and it is necessary to integrate this component with the rest of the architecture layers. The interactions between *DTN repository, bundle, transport, and network layer* have a similar pattern with the interactions of the cross-layer architecture, as it is shown in figure 2. This kind of communication could be used to support policies for autonomic systems.
The bundle layer coordinates and leads the interactions. However, the knowledge provided by the *DTN application* is required by the *transport* and *network* layer too. For example, in the transport layer when a custodian is changing of region within the vehicular network, it is required to obtain the list of segments under his command, in order to assign it to others custodians; or when a node is disconnected and it is necessary to change the route of a specific packet or the dissemination strategy.

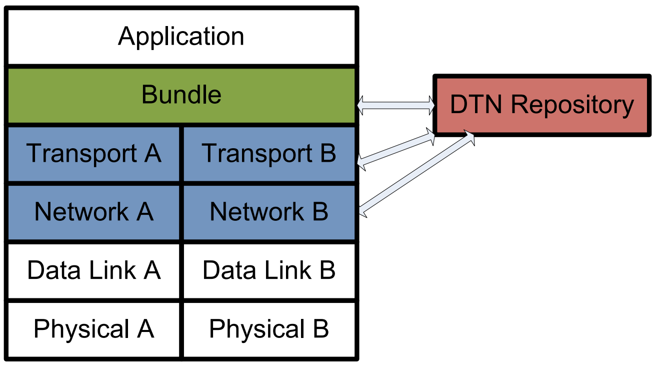

Figure 2. Architecture Layers

4. Application Scenario

The architecture sustains the communication in three planes, 1) inside of the vehicular network, 2) the local server and, 3) the global server, taking advantage of the internet access. To explain this scenario we suppose that there is a duplication or inconsistency problem. One custodian starts the process of transferring to other custodian the responsibility for carrying a message since its storage resources have become limited; but, the custodian who sent the transfer request did not receive the acknowledge of the receiver custodian. Then, both custodians are responsible for the same message. In the first step the vehicles can share and implement different strategies to forward messages, additionally in each region there exists a base station, which has access to the local server. When this kind of problem emerges it is easily solvable, because the sending custodian can check in his local network which custodian is the responsible of the packet and according to this record, it transfers the responsibility to the other custodian. This process is the second step. In the case there are not records in the local server, the last step arises. The sending custodian can check in the global server, which has a higher availability. As a result consistency, storage optimization is provided, and it is possible that the local or global server storages messages when the custodians have limited resources.

There exist many challenges in VDTN as mentioned in *The challenges of disconnected delay-tolerant MANETs* [4]. However, with this type of architecture the challenges related to the little or inexistent infrastructure, inconsistency, high loss rate, and low reliability, can be significantly improved.

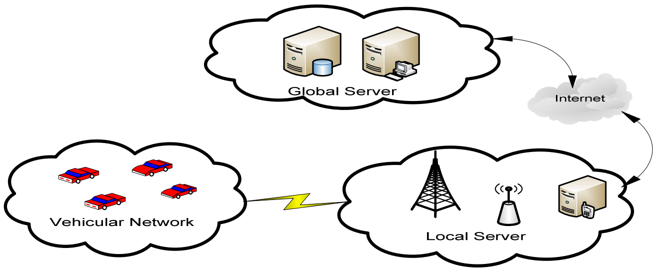

Figure 3.Scenario

5. Performance & Evaluation

The proposed architecture is analyzed according the attributes and procedures applied in the control messages. Table 1 presents a comparison between our approach and DTN architecture.

Table 1. The comparison of control messages methods between the architectures

Architecture	DTN Architecture	Our Approach
Buffer Overflow Management	It removes messages accordingly to its policy.	It removes messages, and it performs message delegate to local server.
Inconsistency	Usually	Rarely
Delay Support	Yes	Yes, but the time to delivery is less than DTN architecture.
Exchange Method	It is based on acknowledgement messages.	Acknowledgement messages plus synchronization messages servers, and services messages (to select the best custodian).
Control Mechanism	Reactive, it uses TTL to wait the acknowledgment messages.	Proactive, it sends control messages through the best path accordingly the node's current position.
Delivery Time	It depends of the disconnection time and the number of hopes	It uses the same method of DTN architecture, but if the communication with base station appears, it reduces the number of hops or it provides availability through other path.
Resources Location	Nodes	Nodes and server.

As shown in Table 1, one of the most outstanding advantages of our approach is the delivery time, because it helps to make communications more reliable and with less congestion. Another important factor is the inconsistency which is reduced using our architecture. Moreover, it incorporates the synchronization of control messages. Note that it is necessary to include servers in our approach, however the network resources are managed more efficiently and it is possible use this infrastructure to perform other important tasks such as handling id / locators, or to implement dissemination methods.

Experiment:

The main goal of the experiment is to test our architecture's efficiency. Therefore, we select the problem of the acknowledgements in a DTN environment. To solve this problem, we implement the method called Custody-Synch Acknowledgment. This method uses the local and global server to control the acknowledgements within the vehicular network when disconnections appear.

The experiment is based on the experiment of *Storage Usage of Custody Transfer in Delay Tolerant Networks with Intermittent Connectivity* [8]. Therefore, we get the results of End-to-end acknowledgement and Custody transfer acknowledgment. The Custody-Synch acknowledgment results include the server infrastructure required by our architecture.

The simulation environment is developed using YACSIM to perform the requirements of the particular DTN storage required to implement custody transfer mechanism. This simulator has the ability to allow for highly variable latency, intermittent connectivity, storage management, and traffic generation. For the purpose of this experiment nodes are modeled as storage nodes, links used delays and capacity parameters, and the intermittently connected links with on-off percentage of 75/25 (75% on, 25% off), 10 intermittent links are used.

In Table 2 we compare our Custody-Synch Acknowledgment method with the other mentioned methods.

Table 2 shows three important criteria: 1) Intermittent links, this are the intermittent connected links, for the experiment this links have two levels, high number (between 8 and 10 links) and low number (between 1 and 2 links). 2) Dropped packets, shows an environment with storage constrains, assuming 1MB storage at each node and 4MB at each node for intermittent connectivity, when the storage constraint is reached the packets are dropped. 3) Network storage, each DTN node performs its own storage management, this criteria represents the network storage used in percentage (%).

The results obtained for methods of Custody transfer and End-to End Acknowledgement clear shows that Custody Acknowledge has better performance while significantly reducing the number of dropped packets and minimizing network storage usage. Our contribution is the Custody-Synch Acknowledgement method which shows that dropped packets are reduced 3% with low intermittent link level and 20% with high intermittent link level, compared with the Custody transfer method. Also the network storage usage is reduced 4% with low intermittent link level and 20% with high intermittent link level. Therefore, our approach performs better when the servers are actively involved in the process.

Table 2. The comparison of acknowledgment methods

	Intermittent links	**Dropped packets**	**Network Storage**
Custody Transfer Acknowledgment	High number	40%	50%
	Low number	5%	7%
End-to End Acknowledgement	High number	60%	100%
	Low number	70%	12%
Custody-Synch Acknowledgment	High number	**20%**	**30%**
	Low number	**2%**	**3%**

6. Conclusions

The vehicular delay tolerant networks have many important applications and every time it is needed to be more accurate, thus the reliability is a key factor to solve many challenges within these types of networks. We propose an architecture that handles very well the consistency and provides more resources to improve the reliability in the communications when disconnection appears.

The future works are: to define protocols working together with the architecture and provide a reliable communication in the vehicular delay tolerant networks.

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