A Context-aware Protocol for Location Discovery Exchange in a Ubiquitous Environment

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Abstract

Due to the dynamic nodes' movement and their interaction, it is challenged to represent, discover and exchange location information in a ubiquitous environment. In this paper, we present a new approach to location information awareness that organizes the format of nodes' location information and maintains the communication between direct nodes in a ubiquitous environment. The structure of Context information Base (CiB) and Context information Communication protocol (CiComm) is manipulated to implement the proposed features.

Keywords: *Context-aware, Ubiquitous Computing, Location-aware, Service Discovery.*

1. Introduction

The operation of a context-aware application or object depends upon context abstraction and representation, retrieval and storage, and communication, which achieves context exchange when combined. Fundamentally, it is the quality of context information and its exchange [1] that ultimately determine the effectiveness of context-aware applications. However, current context exchange approaches suffer from a lack of standards for defining and representing context information. The challenge also comes from the adoption of existing communication protocols, which are not optimized for the requirements of context exchange within dynamic pervasive and ubiquitous environments [2, 3].

This paper introduces a new protocol for the purposes of location information exchange within a ubiquitous environment. The protocol is based on our previous research achievement, that is, a Context information Base (CiB) which provides context representation and storage, so that location information can be encapsulated and ready for sharing.

2. Related Work

Context exchange addresses two key challenges: the representation of context information and its communication efficiency. Early work used Object-Oriented Design (OOD) to represent context information, where Time, Location, Device, User and Network were defined as specialized classes inherited from a base class, ContextObject

[4]. Equally, The Web Ontology Language (OWL) has been used as a means of defining context [5, 6]. However, it is difficult for these methods to build up a standardized and consistent architecture to represent context due to the fact that anyone can define any context information using any representation language. Furthermore, they suffer from redundant and/or conflicting context representation approaches; that is, the same context information can be defined differently, depending on what representation is used and how designers understand it.

In [7], a cross-layer routing protocol was discussed regarding energy consumption as context for better route discovery. Information e.g. Power consumption for Transmitting and Receiving, Angle of Arrival (AoA), etc. was collected to determine optimized routes. It has shown that the more context information had been collected and processed, the better routes the protocol finds.

Trust values were calculated in [8] through a schema for nodes in a mobile ad hoc network. Previous interactions, observation of present behavior, recommendation from direct-paired devices were considered as context information. Therefore, a node's trust can be built as context based on the entire collection of such information.

A location-aware algorithm was presented to broadcast messages in a mobile ad hoc network [9]. It uses zones based on neighbor positions to allow or deny forwarding. Through the results, it depicts better performance than other broadcasting algorithms in low densities.

3. A Context-aware Protocol for Location Information Exchange

Every packet transmitted in CiComm can be divided into a packet header and a packet body. The length of a packet header is fixed to 13 bytes, which contains three fields, i.e. CiB_src field (6 bytes), a CiB_dst field (6 bytes) and a Flag field (1 byte).

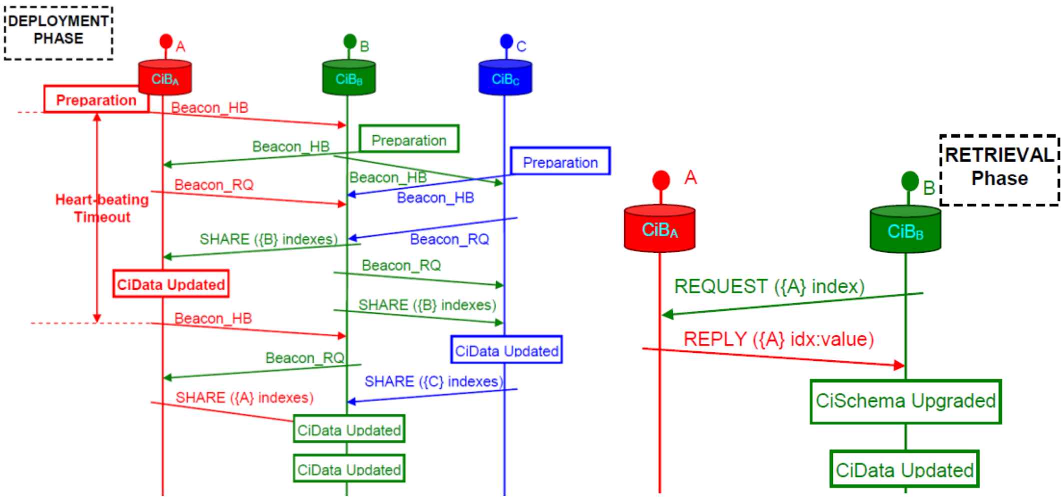
The cctype (4 bits) attribute identifies the type of normal CiComm packets. The bctype (2 bits) attribute specifies the type of CiComm beacon packets. The cftype (2 bits) attribute denotes if the packet is directly sent or forwarded. Table 1 depicts the contents of these three attributes.

Three normal CiComm packets represent different roles in the protocol. They are SHARE, which shares the context index of the host; it can contain context index of proximity nodes which have registered in the host; REQUEST, which requests the actual value of particular context information; and REPLY, which replies the value of the requested context information.

The CiComm protocol operates in two phases, i.e. the Deployment and Retrieval phase. In the Deployment phase, as shown in Figure 1a, Beacon_HB packets are broadcast by all nodes periodically. A Beacon_RQ packet is then returned if two devices are proximate and new to each other. Having received a Beacon_RQ, the receiver will respond with a SHARE packet containing index numbers of context information that the device has. At the end of the Deployment Phase, each node will receive its active neighbors' sharing information. A heart-beating timer is set in a node to ensure the transmission of Beacon_HB packets, which consequently commences the Deployment Phase.

The Retrieval Phase aims to get exact values of particular context information from specified nodes and then to distribute this to other surrounding nodes. As shown in Figure 1b, a REQUEST packet is generated to acquire detailed context information. A REPLY packet is then generated with the requested value. The reception of the REPLY packet will cause CiB updates.

No strict dependencies are set on either of the phases; that is, either of the two phases can be started without the completion of the other one.



(a) Deployment Phase (b) Retrieval Phase

Figure 1. CiComm Packets and Operations in the Deployment and Retrieval Phase

4. Performance evaluation

The new CiComm protocol has been implemented into the NS-2 modules offering location-awareness to nodes. We examine the impact of network density and packet volume on the performance of the protocol.

4.1. Coupling Level and Heart-beat Timer

Coupling Level is defined in our paper to measure the network density. It is the average number of active neighbors that a node is able to communicate with directly. For example, the coupling level of a typical Bluetooth Piconet containing a master and seven slaves is 1.75, because the slaves can only communicate with the master. In a ubiquitous environment, nevertheless, the coupling level of the same topology is 6, since all nodes can communicate with each other in such an environment.

In the CiComm protocol, another parameter that determines context information traffic is the Heart-Beat timer, designed originally to control how often a node broadcasts a Beacon_HB packet. In our simulation scenario, the Heart-Beat timer is set to 1 second and 3 seconds to evaluate the performance of the protocol.

4.2. Scenarios and Evaluation Metrics

The simulation repeats with the nodes number incremented by 1 from 2 to 30. Then the entire job is repeated again with the Heat-Beat timer being changed to 3 seconds. In each simulation, the coupling level is constant (i.e. equals to NodesNumber-1), considering the simulation area and the communication range.

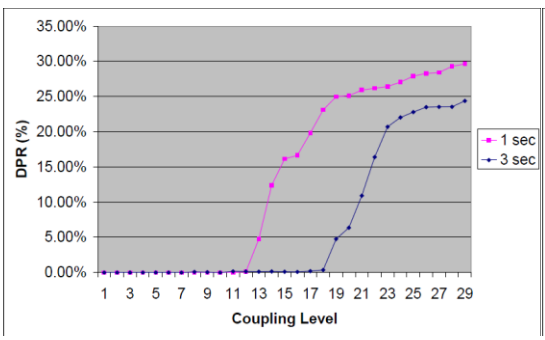
Three evaluation metrics are employed to examine the CiComm performance. The Dropped Packet Ratio (DPR) measures the ratio of dropped CiComm packets to the total offered traffic. The Learning Time is used to calculate the period from an RQ beacon is sent until an appropriate SHARE packet is received. The Goodput counts meaningful bits per second that has been successfully received by all devices in the network. In this case, the meaningful bits are CiComm beacons and normal packets transmitted in the network.

4.3. Simulation Results and Evaluation

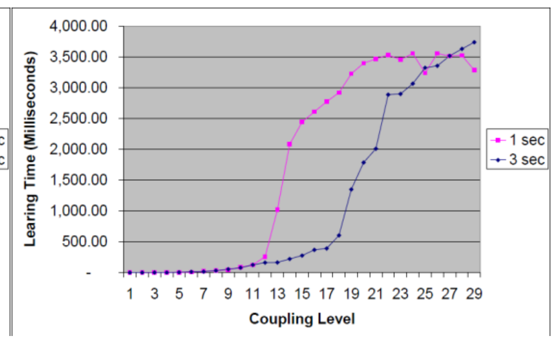
The simulation results are depicted in Figure 2. In Figure 2(a), when the HB timer is set to 3 seconds, the DPR keeps close to zero until the coupling level equals 18. Then, it goes up sharply until 23, after which its rate of change slows until it reaches a final value of 24.37%, when the coupling level is 29. Comparing to the Heart Beat timer of 1 second, the DPR with the HB timer of 3 seconds is always no higher than it.

In Figure 2(b), both learning time lines are almost the same before the coupling level reaches 12. After that, the curve representing HB of 1 second starts to increase considerably, whereas the curve for HB of 3 seconds does not rise until the coupling level is 17.

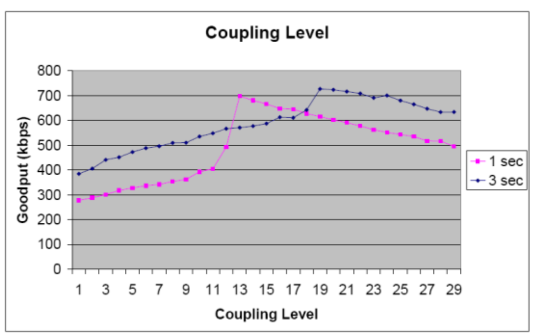
The Goodput is illustrated in Figure 2(c). Again, both scenarios share a similar trend. The Goodput in the HB of 3 seconds scenario is higher than the HB of 1 second scenario in most of the coupling level cases because less HB beacons are transmitted in this scenario.



(a) DPR against Coupling Level with the Heart-Beat Timer altered



(b) Learning Time against Coupling Level with the Heart-Beat Timer altered



(c) Goodput against Coupling Level with the Heart-Beat Timer altered

Figure 2. Performance Evaluation: (a) DPR; (b) Learning Time; (c) Goodput

Through the results, it can be noticed that an increase of the HB timer improves the CiComm performance. A longer HB timer makes HB advertisement less often in each node, generates less CiComm packets, and offers larger gap for context exchange in CiComm. On the other hand, an increase of the coupling level generates more CiComm packets.

A critical threshold can be find in these results, which makes itself a watershed for three metrics. The threshold specifies a point where the demands of the CiComm protocol exceed the capacity of the interface queue in each device to carry CiComm packets. Furthermore, this threshold varies with other metrics that influence the CiComm traffic, such as the HB timer.

5. Conclusion

In this paper, we present a new communication protocol, CiComm for location information exchange in a ubiquitous environment. CiComm employs the concept of context representation model and CiB.

The protocol has been simulated in NS2. The coupling level is defined measuring network density and helps to examine the features and operation of the CiComm. It is observed that a critical coupling level can be determined, over which network contention and buffer overflow happen because of high volume of traffic generated by large number of coupled devices

In a summary, two important criteria have been considered in this paper to evaluate the proposed location-aware communication protocol, involving coupling level and heart beating timer. According to the simulation results, the performance of the CiComm protocol is related to the two parameters. Given either of these two criteria being constant, the increment of the other one influences the protocol performance to a certain extent. A critical threshold is recognized, which determines network contention because of generated CiComm traffic. The threshold varies with different configuration of two criteria, but it indicates a significant point, under which location information is shared among the network with less contention and buffer overflow for queuing processes.

Our next research work will be based on the CiComm, but try to find more criteria that influence the CiComm performance. Moreover, other network traffics are being considered to be added into the scenarios in order to investigate their impacts on the CiComm protocol.

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