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SUPPORTING QUALITY-OF-SERVICE OF MOBILE COMMERCE TRANSACTIONS

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ABSTRACT

With the deployment of 3G and 4G mobile networks, a sizable proportion of e-commerce traffic is expected to move to these networks. These transactions are likely to be diverse. Mobile transactions can include unique requirements such as atomicity (all or none steps), push or pull, security, and privacy. Some mobile commerce transactions may not be completed because users are mobile, unpredictable link characteristics, and other problems associated with wireless networks. Therefore, the probability of completing mobile transactions is an important parameter for measuring quality-of-service of a network supporting mobile commerce. The transaction completion probability measures the ability of networks to support completion of transactions. This research focuses on improving the support of mobile commerce transactions by the underlying wireless networks. Mobile commerce traffic is classified as messaging, information connectivity, and transactions in order to provide efficient quality-of-service to various applications. This paper introduces the use of priority, sociability and delegation to improve the transaction completion in wireless networks.

KEYWORDS: wireless networks, quality-of-service, mobile-commerce, mobile transactions

I. INTRODUCTION

With the increasing deployment of 3G and the predicted emergence of 4G mobile and wireless networks, a sizable proportion of e-commerce traffic is expected to move to these networks. The number of internet users is likely to grow from 533 million in 2003 to 1.4 billion by 2007 [Magura, 2003]. The number of wireless internet users, as a proportion of the total internet users worldwide, is likely to grow from 16% in 2003, to 57% by 2007 [Magura, 2003]. Wide adoption, aided by deployment of secure and efficient technologies, is likely to spur further growth in mobile commerce, and create fertile conditions for emergence of many new applications with *anywhere-anytime* characteristics. However, some of the earlier projections of the growth in mobile commerce needed to be scaled back [Haskin, 1999].

Even though the business potential for m-commerce is not disputed, a wide adoption of the technology did not materialize. These projections were made based on the success in e-commerce adoption. A distinction between e-commerce and m-commerce needs to be made in the context of transactions. E-commerce is defined as

The buying and selling of products and services facilitated by computer networks.

E-commerce is better equipped for supporting and realizing transactions compared to m-commerce [Stafford and Gillenson, 2003]. The existing wireless networks and protocols do not support transactional applications very well [Stafford and Gillenson, 2003; Batista, 2002]. This paper proposes several conceptual solutions to improve the quality of service support for mobile transactions.

AN EXAMPLE

The following is an example (based on Vandermeer, D. et al. [2003]) of a typical mobile transaction in which a user purchases an airline ticket by using a mobile device connection to the Internet through a wireless network. Purchasing an airline ticket might be considered an overall transaction comprising of several sub-transactions. A user intending to purchase such a ticket typically logs into the airline's server, checks his or her frequent flier account, indicates the preferred dates and times of travel, makes a selection from different travel options provided by the airline, selects the preferred seats and meal options, and provides credit card details to finally purchase the ticket and receive the confirmation. These sub-transactions might involve - different services of various agencies located on different networks, a workflow process requiring a pre-specified sequence of actions, interaction of the user with different systems, and time separation between different steps of the process. To complete this transaction successfully, the network connectivity must be maintained for the entire duration. If the user's wireless connection drops, as occurs frequently, during the purchase step, she must reconnect to the Internet again and restart the process. Significant amounts of time and resources are wasted in redoing previously completed work. The resources expended in such partly completed transactions are not recoverable.

Clearly, an abrupt interruption in the middle of a financial transaction would cause much greater anxiety to a user compared to dropping a simple voice call.

The foregoing example illustrates the need for differentiating among mobile applications, and for the networks to provide suitable service to each. A number of transactional applications are expected in the wireless domain. Some examples of these applications are: mobile financial transactions, mobile shopping, and mobile entertainment contents. It follows that a taxonomy of mobile applications needs to be developed before studying their quality-of-service (QoS) characteristics. Although significant research results exist on quality-of-service in voice and/or packet oriented communication in wireless networks, the research community only recently began to focus on quality-of-service in the context of mobile transactions [Ahluwalia and Varshney, 2003].

This paper examines the problem of providing quality-of-service to mobile transactions. Specifically, it investigates the middle-of-the-session interruption scenarios in mobile transactions and proposes three conceptual link and network layer methods to increase the probability of transactions completion. Implementation of the proposed methods could impact product and price differentiation strategies, and affect network management policy issues such as the user admission/user blocking.

The resource constraints in wireless networks preclude the possibility of a generic solution universally applicable to all traffic types. The level of quality-of-service is closely tied to the resources provided to the applications seeking connections. A balance between conflicting demands of providing better QoS guarantees and maximizing resource utilization needs to be found. Hence the quality-of-service solutions should be closely aligned to the requirements of the particular classes of transactions.

Because the transactions expected to be supported by wireless networks are diverse, it is necessary to classify mobile commerce transactions on the basis of their characteristics and the unique requirements they bring upon wireless networks so that optimum QoS can be provided to them. In Sections II and III, we discuss the existing literature on mobile/wireless applications to underscore the diversity of QoS requirements of mobile transactions. We then present a conceptual typology of mobile transactions (Section IV). Three methods to improve the transaction completion probability are presented in Section V using this typology.

The main contributions of this paper are:

- Presentation of diversity in mobile transactions.
- Examination of their quality-of-service requirements.
- Three proposed methods to support transactions under conditions of intermittent disconnections.
- The implications of the proposed solutions and the directions for future research.

II. RELATED WORK

Supporting quality-of-service for mobile users in wireless networks is an active area of research. Most of this research is based on the need for allocating resources efficiently to mobile users at the connection level. Chalmers and Sloman [1999] provide an excellent survey of major traditional QoS methods in wireless networks. The examples of traditional QoS support are:

- admission control [Naghshineh and Acampora, 1996; Levine et al., 1997],
- efficient resource allocation methods [M. El-Kadi and Abdel-Wahab, 2002; Das et al., 1997], and
- use of mobility and user characteristics for resource allocation [Ye et al., 2002].

The detailed performance comparison of a number of QoS methods can be found in [Choi and Shin, 2000], and QoS issues with respect to 3G networks are discussed in [Maniatis et al., 2002]. The more recent work on QoS deals with

- exploiting the adaptability of mobile applications [Liao and Campbell, 2001; Gomez and Campbell, 2003],
- optimum resource allocation for multimedia traffic [Chen et al., 2002; Bartolini, 2001],
- scalable QoS support [Sadeghi and Knightly, 2003],
- QoS in and across multiple heterogeneous wireless networks [Stemm and Katz, 1999; Varshney and Vetter, 2000, Bianchi et al., 2003] and
- fault-tolerant or dependable quality-of-service [Tipper et al., 2002; Varshney, 2003].

A need for specific QoS metrics to represent adequately the ability of wireless networks to support mobile commerce transactions is stressed in Ahluwalia and Varshney [2003]. Some mobile transactions may not be completed in accordance with their workflow specifications due to the users' mobility, unpredictability of the link quality, and other problems associated with wireless networks. As pointed out in Section I, from a user's perspective, an incomplete mobile commerce transaction is likely to lead to a significantly higher anxiety than dropping a voice call. Therefore, the probability of completing a mobile transaction is an important parameter for measuring the QoS in wireless networks supporting transaction applications.

The new metric of "transaction completion probability" measures such QoS performance [Ahluwalia and Varshney, 2003]. *Transaction completion probability* is defined as the ratio:

$$\frac{\text{the number of transactions completed,}}{\text{the total transactions attempted}}$$

where the total transactions attempted includes those which are aborted, blocked or dropped.

The probability of completing a transaction is impacted by the type of transactions and by the ability of the network to provide the requested resources during a transaction. Furthermore, the transaction completion is also affected by the delay requirements[1], because it may be possible to support higher proportion of transactions with a more relaxed delay requirements.

Summing up, the existing literature suggests three different dimensions of quality-of-service in wireless networks. These are:

- Connection level QoS.
- Packet level QoS.
- Transaction level QoS.

Figure 1 shows a framework of quality-of-service research in wireless networks. The three dimensions of quality-of-service along with their individual components are shown in the figure. In this paper, we propose methods to improve the probability of the transaction completion metric.

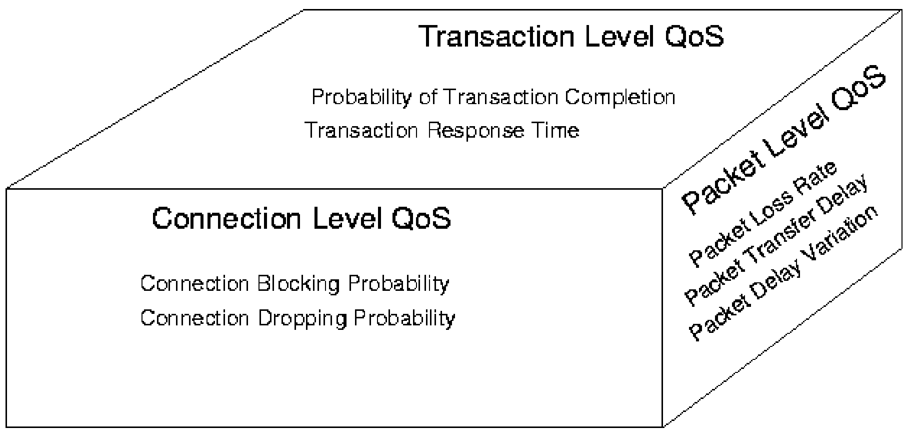

Figure 1. Multiple Dimensions of QoS

III. DIVERSE CHARACTERISTICS OF MOBILE TRANSACTIONS

A three dimensional framework presented by Varshney and Vetter [2002] to organize research and development in mobile commerce is being widely followed. This framework includes four levels:

1. applications,
2. user infrastructure,
3. middleware, and
4. network infrastructure.

The methods proposed in this paper belong to the network infrastructure domain of the network in the framework.

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[1]All transactions should be completed within a certain time. Some transactions may be flexible in their “time to complete” parameter. We call this parameter the delay requirement. The lower the delay requirement – more stringent the requirement.

Mobile commerce transactions range from the simple non-real time unicast to the full-scale real-time multicast across multiple heterogeneous wireless networks. These transactions can be local or end-to-end, symmetric or asymmetric, requiring different levels of reliability, and could last from less than a second to several minutes and even longer. The transactions can be one way, two-way, or multi-way involving a range of entities, some mobile and some not. Many of the mobile commerce transactions are likely to be asymmetric, i.e., they require different performance in the two directions of traffic.

Several applications supported by wireless networks are transactional in nature such as mobile auctions, mobile entertainment services, wireless data center, mobile financial services, mobile advertising and shopping, and location-based services [Varshney, 2003; Kalakota and Robinson, 2001]. These applications could be local or end-to-end. The local transactions are defined as the ones in which all steps are conducted in a single wireless network. In contrast, the end-to-end transactions involve entities spread over multiple wired or wireless networks, and such transactions are conducted over multiple networks.

Atomicity, identified as an important characteristic of transactions, is defined as "either all happen or none happens" [Gray and Reuter, 1993]. Some mobile transactions may require atomicity. This condition requires that if a transaction step fails due to user mobility or brief disconnection, the whole transaction must be aborted after a certain timeout. An example of such transactions is a mobile financial service, where all steps must be executed or the whole transaction must be aborted. All steps must be successfully completed without the users involved being disconnected. The aborted transactions could be re-tried but would result in greater expenditure of resources because the resources consumed in the partly completed but aborted transactions are completely wasted. Figure 2 shows the range of characteristics of mobile applications.

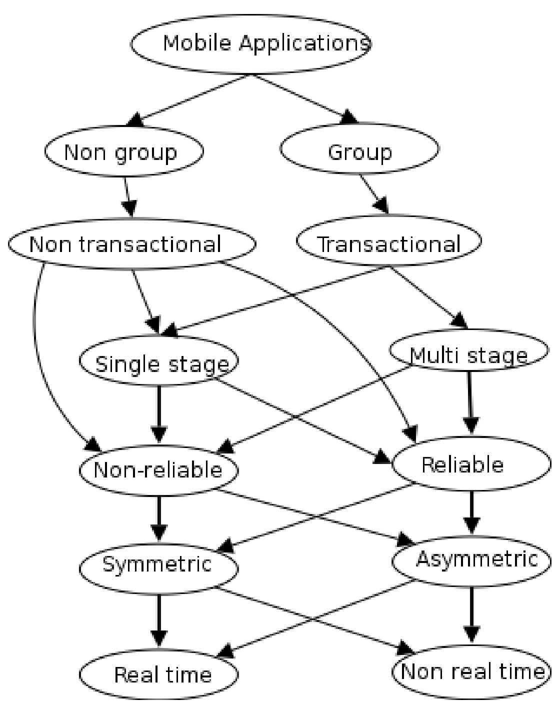

Figure 2. Mobile Applications and Transaction Requirements

Until now, the problems arising in mobile transactions were studied in the contexts of distributed databases operations, maintaining file consistency, and resource constraints of mobile devices. A review of literature found no study on improving transaction completion probability in mobile networks. In this paper, we propose methods to improve transaction completion probabilities especially of the atomic transactions. A greater number of completed transactions will also result in higher resource utilization efficiency because fewer transactions will be re-tried, resulting in resource savings.

IV. TYPOLOGY OF MOBILE APPLICATIONS

The third and fourth generation wireless networks are expected to support many traffic types.. An efficient QoS method should be flexible and able to adapt to the network conditions and application requirements. Thus, for a given set of conditions, an optimized solution exists. However, a separate QoS method for each mobile application will make overall network QoS management complex. Therefore, it is better to classify various applications based on their characteristics and QoS requirements.

Three broad classes of mobile applications are considered for the purposes of subsequent discussion about the link layer and network layer methods proposed in Section V. These classes are mobile transactions, information retrieval, and messaging.

MOBILE TRANSACTIONS

These are *atomic* applications, typically involving economic implications for the users. Traditionally, these applications are interactive, requiring user involvement. The transactions may or may not require response time constraints. High reliability is important. A user purchasing an airline ticket through a mobile device is an example of mobile transactions.

INFORMATION RETRIEVAL

These applications are typically real time in nature, but do not usually result in economic loss when aborted before they are voluntarily terminated by the user. If aborted, they can be restarted without losing the value of partly completed applications. Reliability requirement is not as high as in the mobile transactions. A user querying a search engine for any information using a mobile device is an example of this class of applications. Economic losses can occur if the information sought is needed immediately.

MESSAGING

These non-real-time asynchronous applications do not require user interaction until they are completed. Messaging applications can be stored and queued in the network, and can be transmitted when adequate resources become available. SMS (Short Message Service) is an example of this class of application.

V. PROPOSED METHODS

In this section, we propose three conceptual methods to support completion of mobile commerce transactions under the conditions of temporary or permanent disconnections. These methods are designed to facilitate completion of mobile transactions even when the user’s wireless channel with the access point is impaired, and the user can no longer continue a session directly through the established route.

The network model considered in this section assumes an infrastructure-based wireless local area network. All users make connections through an access point. We also assume that the channel between a user and the access point is the only wireless link of connections. Figures 4 through 7 represent this architecture.

The proposed methods seek to re-establish either the link when the channel quality between the user and the access point is impaired, or consider alternate ways to complete the affected transactions. The three methods are independent and exclusive of one another. They may be applied individually or in a hierarchical order. The methods are designed on the basis of the concepts of sociability and trust of users in/with other network entities. The methods also consider prioritization based on the class of application. Implementation of these methods can result in higher probability of transaction completion, thus enhancing the overall quality-of-service as well as the resource utilization efficiency in wireless networks with mobile transactions.

The success of a session in wireless networks depends largely on the link quality during the time the session is in progress. A poor quality link is likely to result in intermittent or permanent disconnections of a mobile commerce session. Disconnection of a session can lead to the termination of an on-going mobile commerce transaction, thereby resulting in many undesirable effects, such as loss of opportunities for the users, loss of revenues for the wireless service provider, loss of confidence and trust of users in the technology. Even though the disconnections can not be completely eliminated, alternative means of completing the transactions could be explored. A better quality-of-service performance can result if alternate methods could be found to continue to support the transaction even though the users are disconnected from the access point temporarily. A high rate of successful, safe and secure completions of transactions, is crucial in facilitating wide spread adoption of mobile commerce applications. The three proposed methods are:

- Prioritized link allocation.
- Connectivity through trusted friends.
- Connectivity through delegation.

Each of the methods is now explained in detail followed by a discussion about implications arising out of their implementation.

PRIORITIZED LINK ALLOCATION

This method gives higher priority to transaction slots, in comparison to other competing flows, in the channel allocation algorithm. Transaction service type is a critical application from a user's perspective since it involves business transactions with economic implications. The goal of the link layer is to provide a good quality link to a connection during a transaction. When all flows cannot be transmitted due to bad link quality, a weighted priority approach should be used in the scheduling algorithm which assigns channels to different competing flows. It would be necessary to provide preferential access first to the links engaged in transaction service compared to other applications. Normally, a scheduling algorithm seeks to achieve fairness among all competing flows. However, considering that costs of disruption are higher for mobile transactions over information retrieval and messaging applications, the criteria of equal fairness may not be desirable. In the proposed method, mobile commerce transactions flows are given the highest priority by the scheduling algorithm (see Figure). Existing transactions are given higher priority over new transactions. The value of weighed priority can be set by a network provider to determine the extent to which preference is accorded to flows with mobile transactions traffic. Under this method, the information retrieval class of traffic is accorded the second priority followed by the messaging applications. Messaging applications are not time sensitive. The packets carrying messaging applications data can be buffered and sent when the channel becomes good, and when there are no other mobile commerce transactions competing for the same resources. For the link layer to distinguish among service types, the packet header needs to be flagged. Selective error control algorithms can also be used to deal with bit error problems caused by bad link quality, though at some expense due to increased overhead.

Figure 3 shows a scenario of re-arranging of slots by a scheduling algorithm. The top row shows the slots for various applications as they arrive in time sequence and the bottom row shows re-arranged slots according to a weighted priority for sub-transactions, before being served by the link allocation server.

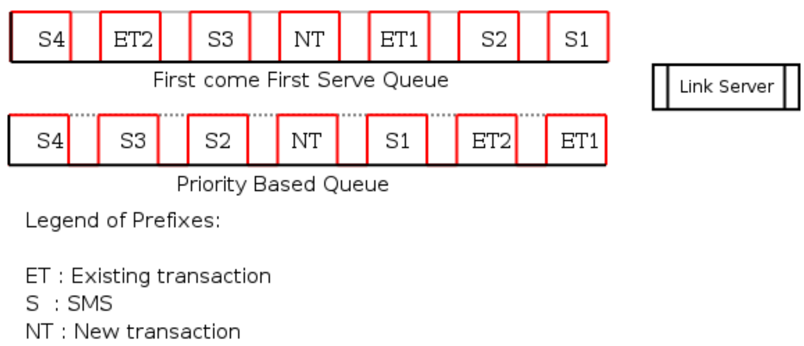

Figure 3. Prioritized Link Allocation

CONNECTIVITY THROUGH TRUSTED FRIENDS

This method uses the concept of *sociability* of users to find alternative routes for their connections when the direct connection with the access point is disrupted. This method is represented in Figure 4. In this figure, “U” inside the double circles is the user in the middle of a transaction, “TU” represent trusted users or friends of the user “U”, “DU” are distrustful users for “U”. Arrows represent the users’ mobility.

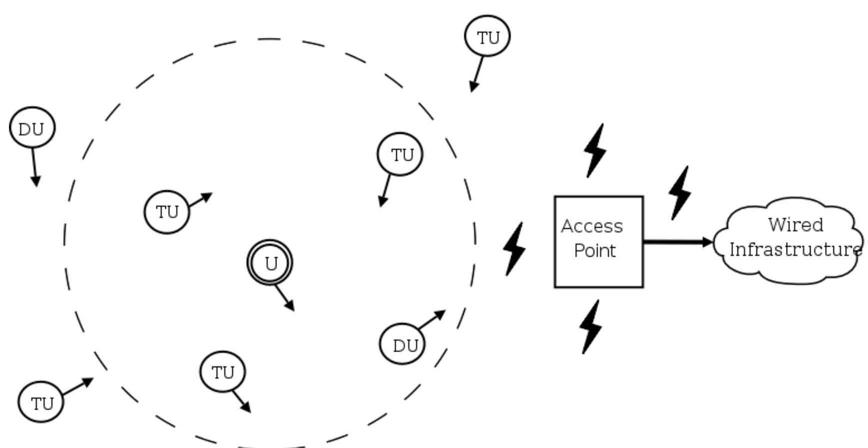

Figure 4. Connectivity through Trusted Friends

To explain this method, consider a scenario in which the link quality of a connection for user “U” was good when the transaction began. However, It became bad shortly thereafter before the transaction could be completed. In this situation, two possibilities exist. First, the connection may get re-established fairly quickly as the mobile user may move to a location where the link quality is good. The second alternative is to find a different route for the transaction. It may be possible that link quality between the trusted friends of the user (TU) and the access point is good. In that case, the routing of the connection can switch through one of the trusted user in an ad-hoc network configuration. The method assumes that there will be a sound link between one of the trusted users and the access point, and also between the user and the trusted friend. It is evident from the figure, that more social the user is, that is it has greater number of trusted users, greater is the probability it could seek help from them when faced with a disconnected transaction. Another implication of this method is for the network providers. They may setup pricing, QoS and other policies to discourage *distrustful* users, and to encourage users who have greater *sociability.*

In this method, the user must know the locations of its trusted users, because the user would be able to establish connection only with those who are in the user's zone of access. This zone is shown as the area inside the dashed circle in Figures 4 through 6.

Two location management methods are proposed:

1. All users continuously transmit beacon signals. The user receives the beacons of all other users in its zone of access, and records the presence of all of its trusted users. Figure 5 shows this method. If the user does not receive a beacon for a time exceeding a certain pre-set time from a trusted user, it assumes that the latter moved away from its zone of access and deletes its entry in its database. Even though simple in design, this method requires an expenditure of power consumption in the devices because frequent beacons must be sent.

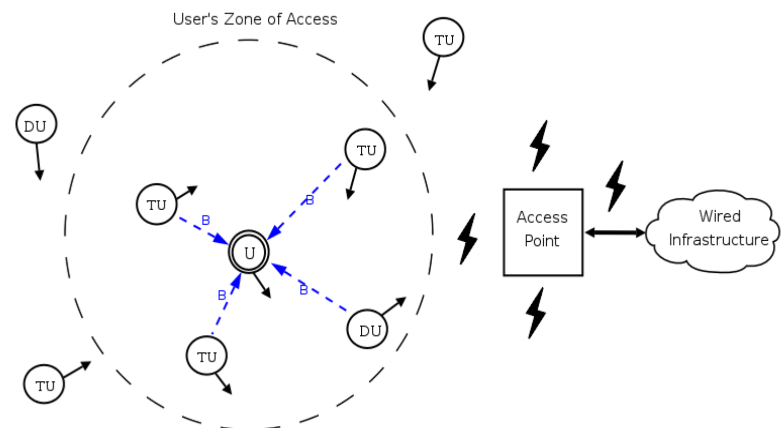

Figure 5. Locating Trusted Users through Beacons

2. The second method depends on the access point to frequently update the users about the location of their trusted friends. This method is shown in Figure 6. As can be seen in this figure, this method also involves significant overhead because the access-point must send location update messages to users. The amount of overhead can be reduced by doing selective location updates only for those users who are involved in transactions, at any instant.

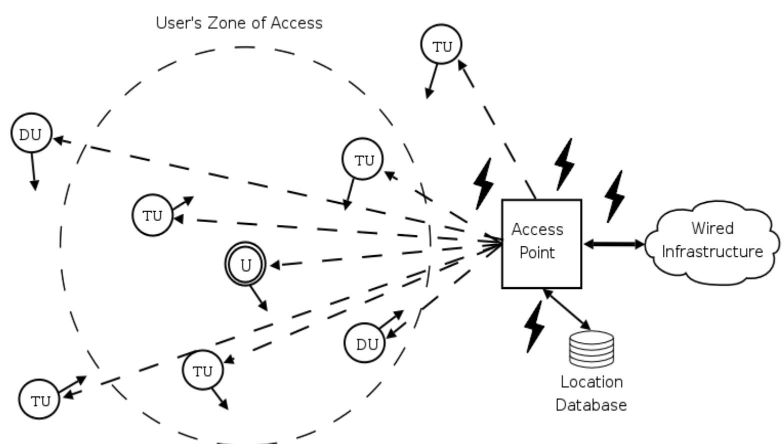

Figure 6. Locating Trusted Users through the Access Point

CONNECTIVITY THROUGH DELEGATION

This method is based on the premise that users can delegate the entire transaction specification workflow specification to the access point. Figure 7 shows this method. Symbol "T_U" represents the user's transaction specification. In this method, the user communicates its intention to engage in a transaction with the access point. The user then transfers to the access-point, all the information needed to complete the transaction, at the time of connection setup. Two possibilities exist. First, the access point can complete the entire transaction, and communicate the results of the transaction to the user when the link quality becomes good. Second, the access point interjects itself into the transaction session only when the link quality becomes bad and the user is unable to complete the transaction directly. In the second case, the access point takes control of the transaction and completes it. The access point acts as an agent of the user during the period when the user is not directly engaged in the transaction. In the second alternative, the access point is required to maintain the "TCP" state information of the user, at all times. Like the two methods discussed earlier, this method also incurs additional overhead in terms of transfer of transaction specification to the access point.

Each of the three methods requires a trade off between the need for increasing the QoS, and increasing the throughput efficiency of resource utilization. As stated earlier, completed transactions may in fact be, more resource efficient, and may improve both the QoS and the resource utilization efficiency.

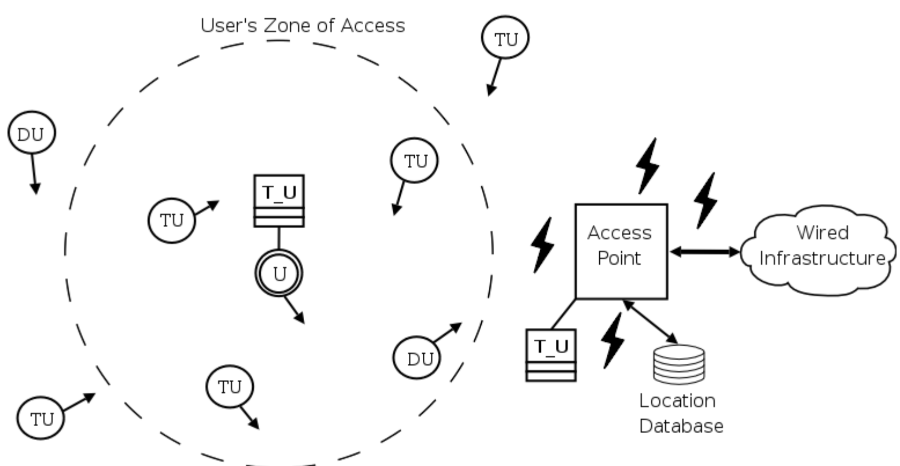

Figure 7. Transaction Completion by Delegation

IMPLICATIONS AND ISSUES

Important issues related to the proposed methods are actions, privacy, communications, overhead, scalability, and multicast transactions. Implications of the implementation of these methods for the network providers are also discussed in this subsection.

Support for Real-Time and Non-Real Time Transactions

Since transactions could either be real-time or non-real time, it would be helpful to be able to differentiate among transactions. The transactions requiring real-time service or very low response time could be re-routed and executed with the support of trusted users or access points. The transactions with moderate tolerance to delays could be allowed to wait for some time until the connectivity improves. The non-real time transactions could be allowed to wait much longer.

Privacy Issue and Trusted Neighbors

Privacy is a significant issue because of the nature of some mobile commerce transactions. Many users are likely to be uncomfortable in letting another user execute their transaction, because that user could potentially access or derive private and sensitive information. To overcome this problem, a list of trusted neighbors could be made before selecting one of the physical neighbors for help in taking over the transaction. The list could be multi-tier where different users are limited to executing or help in executing certain transactions. Another implication is for the network providers who might regulate the presence of distrustful users.

The Amount of Processing and Communications Overhead

The transfer of transaction information from a user to another would add to communications and processing overhead. This cost must be compared with potential benefit of the increased transaction completion probability. To limit the amount of communication and processing overhead, the number of transactions that are rerouted could be limited to a certain number. Another way to reduce the overhead is to reduce the amount of information that must be moved to neighbors by using knowledge about the number of steps already executed reliably.

Scalability of Rerouting Methods

Performance degradation increases as the number of transactions and users increases. For poor quality links, the effective overall capacity of the network is reduced. Since the proposed methods are likely to increase the wireless traffic, ways to reduce the overhead need to be addressed. One possible solution is to use delayed rerouting, where some wait is introduced selectively. In this way, it is expected that some improvement in connectivity could occur if short-term fluctuations decrease during the wait time.

Support for Multicast Transactions

Many of the mobile commerce transactions are likely to require multicast, where several entities and users participate in a transaction. Some of the multicast transactions would also be real-time and parts of these transactions would have to be executed on different nodes or base stations. The effect of dis-connectivity is likely to be different on the users of the multicast transactions than on the users of unicast transactions. If the source of a multicast transaction cannot find a trusted neighbor, the whole transaction would have to be aborted, while disconnection of a non-critical user would still allow the transaction to continue among other users. The number of nodes that assist a multicast transaction could also be limited.

Implications for the Network Providers

The proposed methods could have significant implications on the network management by service providers.

The priority based method assigns priority to transactions over other traffic types. The network provider could exploit this feature to setup service and price differentiation. For example, the transactions could be classified as favored and regular. Users subscribing to the favored transactions method could be asked to pay a higher price over those who subscribe to the regular transaction method. In return, the favored transactions could be prioritized more aggressively than the regular transactions.

In the case of the sociability method, a user profile may need to be maintained by the providers for all users. A typical user profile might consist of indexes related to the user's ability to trust others, and user's social standing. A user's ability to trust others is proportional to the number of users in the network whom the particular user is ready to trust. On the other hand, the metric of a user's social standing is proportional to the number of users who trust the particular user. A new user may have to stay in the network for some time before sociability is established. To solve this problem, network providers may use different methods to ascertain a users' sociability. For example, network providers could share their users' sociability metric with other network providers. Based on the value of the two indexes, network providers may offer price incentives to good users. They may also setup a policy criterion of admitting/retaining users who have a sociability score above a certain level while rejecting others.

The delegation method can also be used to provide service and price differentiation based on whether a user is willing to delegate completion of their transactions to the Access Point. Users whose transaction have greater probability of being completed because of delegation of the transaction workflow specification to the Access Point could be asked to pay a higher price. Users whose transactions probability of being completed is greater because of delegation of the transaction workflow specification to the Access Point could be asked to pay a higher price. Conversely a failed transaction could also be charged to the user for the resources consumed regardless of whether or not the transactions are completed successfully.

Implementations of these methods not only involve design and development of appropriate networking protocols, but also techno-economic evaluations of the overheads caused by each of the three methods. Outcome of these evaluations would help the network providers determine their pricing/policy decisions.

VI. CONCLUSION

Mobile commerce transactions are likely to become an important part of wireless and mobile services. Lack of support for transactions has been identified as one of the main causes inhibiting wide adoption of mobile commerce. Transactions are likely to present a diverse set of requirements. Atomic transactions typically involve execution of pre-identified steps in a given order. Disconnections of the transactions, especially the atomic transactions, before they are completed pose a challenge to the support provided by the network infrastructure. In this paper, we propose three conceptual methods, which provide higher priority to the mobile transactions in comparison to other classes of traffic, and make use of the concepts of trust and delegation to improve the probabilities of transaction completion.

RESEARCH ISSUES

Several research questions arise in light of the issues discussed in this paper. As wireless networks are constrained for resources, feasibility of any method should demonstrate high resource utilization efficiency. The methods proposed in this paper involve some overhead. The feasibility and attractiveness of these methods can be ascertained by conducting performance evaluations either analytically or through simulation.

In this paper, we discussed unicast scenarios in LAN environment. Similar problem but in heterogeneous wireless networks, and in multicast connections need to be researched. Further optimizations in the proposed methods may be possible by considering the issues discussed in Section V, such as resilience to latency.

This paper also discusses implications for the pricing models for mobile transactions. Different pricing models could be developed for network providers considering different scenarios of sociability and delegation.

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REFERENCES

Ahluwalia, P. and U. Varshney (2003). A Link and Network Layer Approach To Support Mobile Commerce Transactions. In *IEEE 58th Vehicular Technology Conference, 2003*, (5), pages 3410–3414.

Bartolini, N. (2001). Handoff and Optimal Channel Assignment in Wireless Networks. *Mobile Networks and Applications*,(6)6, pp.511–524.

Batista, E. (2002). Crappy WAP Bridging Gap. *Wired News.*

Bianchi, G. et al., (2003). Design and Validation of QoS Aware Mobile internet Access Procedures for Heterogeneous Networks. *ACM/Kluwer Journal on Mobile Networks*, (8) 11–25.

Chalmers, D. and M. Sloman, (1999). A Survey of Quality of Service in Mobile Computing Environments. *IEEE Communication Survey,*(2)2.

Chen, H., Zeng, Q.-A., and D. P. Agrawal, (2002). A Novel Analytical Model for Optimal Channel Partitioning in the Next Generation integrated Wireless and Mobile Networks. *Proceedings of the 5th ACM International Workshop on Modeling analysis and Simulation of Wireless and Mobile Systems*, pp. 120–127.

Choi, S. and K. Shin, (2000). a Comparative Study of Bandwidth Reservation and Admission Control Schemes in QoS-Sensitive Cellular Networks. *ACM/Kluwer Journal on Wireless Networks*, (6) pp.289–305.

Das, S. K., Sen, S. K., and R. Jayaram. (1997). A Dynamic Load Balancing Strategy for Channel Assignment Using Selective Borrowing in Cellular Mobile Environment. *Wireless Networks*, (5)3 pp.333–347.

Gomez, J. and A. T. Campbell. (2003). Havana: Supporting Application and Channel Dependent QoS in Wireless Packet Networks. *Wireless Networks*, (9)1 pp. 21–35.

Gray, J. and A. Reuter. (1993). *Transaction Processing: Concepts and Techniques*. Morgan Kaufman.

Haskin, D. (1999). Smart Phones to Lead E-Commerce Explosion. *All Net Devices. Technical Report, Analytics*.

Kalakota, R. and M. Robinson. (2001). *M-Business: The Race to Mobility*. New York: McGraw Hill.

Levine, D. A., I. F. Akyildiz, and M. Naghshineh. (1997). A Resource Estimation and Call Admission Algorithm for Wireless Multimedia Networks Using the Shadow Cluster Concept. *IEEE/ACM Transactions on Networking*, (5)1.

Liao, R. R.-F. and A. T. Campbell. (2001). A Utility-Based Approach for Quantitative Adaptation in Wireless Packet Networks. *Wireless Networks*, (7)5 pp. 541–557.

M. El-Kadi, S. O. and H. Abdel-Wahab. (2002). A Rate-based Borrowing Scheme for QoS Provisioning in Multimedia Wireless Networks. *IEEE Transactions of Parallel and Distributed Systems*, (13)2.

Magura, B. (2003). What Hooks M-commerce Customers? *MIT Sloan Management Review*, (44)3 p. 9.

Maniatis, S., E. Nikolouzou, and I. Venieris. (2002). QoS Issues in the Converged 3G Wireless and Wired Networks. *IEEE Communications Magazine*, (40)8, pp.44–53.

Naghshineh, M. and A. S. Acampora. (1996). Qos Provisioning in Micro-Cellular Networks Supporting Multiple Classes of Traffic. *Wireless Networks*, (2)3, pp. 195–203.

Sadeghi, B. and E. Knightly. (2003). Architecture and Algorithms for Scalable Mobile QoS. *ACM/Kluwer Journal on Wireless Networks*, (9), pp. 7–20.

Stafford, T. F. and M. L.Gillenson. (2003). Mobile Commerce: What It Is and What It Could Be. *Communications of the ACM*, (46)12, pp.:33–34.

Stemm, M. and R. H. Katz. (1999). Vertical Handoffs in Wireless Overlay Networks. *Mobile Networks and Applications*, (3)4, pp.335–350.

Tipper, D. et al. (2002). Providing Fault Tolerance in Wireless Access Systems. *IEEE Communications Magazine*, (40)1, pp.58–64.

Vandermeer, D. et al. (2003). Mobile User Recovery in the Context of internet Transactions. *IEEE Transactions on Mobile Computing*, (2)2, pp.132–147.

Varshney, U. (2003). Location Management for Mobile Commerce Applications in Wireless internet Environment. *ACM Transactions on internet Technology*, (3)3, pp.236.

Varshney, U. and R. Vetter. (2000). Emerging Mobile and Wireless Networks. *Communications of the ACM*, (43)6, pp.73–81.

Varshney, U. and R. Vetter. (2002). Mobile Commerce: Framework, Applications and Networking Support. *ACM/Kluwer Journal on Mobile Networks and Applications*, (7), pp.185–198.

Ye, J., J. Hou, and S. Papavassiliou. (2002). Comprehensive Resource Management Framework for Next Generation Wireless Networks. *IEEE Transactions on Mobile Computing*, (1)4, pp.249–264.

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