Dynamic Agent-Based Prioritized Connection Admission for Stressed Networks

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ABSTRACT

For broadband networks to be widely useful to society, they must dynamically recognize some connections, like those that deal with emergencies or natural disasters, as having greater importance than others. This paper proposes an architecture of geographically distributed ticket servers that issue importance tickets for connection admission. User agents contact ticket servers using an agent communication language, then a ticket server intelligent agent determines how valuable of a ticket to issue within the current context of an emergency or natural disaster. Use of ticket servers and agent communication enables quick adaptation to dynamic context changes and provides high user satisfaction.

I. INTRODUCTION

For modern broadband networks to integrate all types of data and multimedia user traffic, connection admission control (CAC) functions must provide guaranteed, or at least differentiated, quality of service levels. This must occur at the packet level to meet rate and delay specifications, but must also occur at the connection level to give differentiated access to resources.

CAC functions must be able to dynamically designate (and possibly manipulate) some connections as having greater importance than others. Those with greater importance may be those which have greater revenue-generating capability, but also may be those that deal with emergencies or natural disasters. Unless networks can recognize which connections are more important, the potential usefulness of integrated broadband networks is limited. The basic hypothesis of this research is that connection importance can be automatically determined by using geographically distributed importance ticket servers that use intelligent agent communication techniques.

A prime example for the need for managing traffic according to its importance is response to natural and man-made disasters. Recent disasters, like Hurricane Andrew in 1992, the Northridge Earthquake in 1994, and the Oklahoma City Bombing in 1995, all had tremendous communications needs. Public networks were severely congested because communications facilities were damaged and the general public and disaster management personnel generated high loads. During the first day of such events, call volumes can be five times normal levels [1].

In these situations, the general public must be able to communicate about dangerous situations and emergency management personnel must be able to use communications facilities to assess damage, deploy relief efforts, attend to medical needs, and save lives [2]. For disaster management personnel to be able to effectively use public resources, they must have an "emergency lane", a special means of gaining access to public network resources despite structural damage and traffic congestion [3].

Disaster relief occurs in phases. Early phases are concerned with saving lives and assessing damage, while later phases involve economic relief and rebuilding. The importance of a connection depends, therefore, on the dynamic *context*, not only the presence of a crisis, but also disaster response phases within the crisis.

This paper provides an architecture that automatically and dynamically determines which connections should be treated with higher importance than others, so services can be provided accordingly. Section II describes the overall architecture and its use of importance ticket servers. Section III then discusses the difficulties to overcome, with Section IV describing an intelligent agent communication approach that addresses these difficulties. The conclusion of the paper examines the benefits of the architecture and asserts that these benefits outweigh the complexity of implementation.

II. IMPORTANCE TICKET SERVER ARCHITECTURE

Determining and managing connections of differing importance through an importance ticket server architecture is illustrated in Fig. 1.

A. IMPORTANCE TICKET SERVERS

The end user presents requests to network manager agents for connections. To obtain a higher importance connection, the user obtains an importance ticket from an importance ticket server to give to the network manager agent. The network manager agent then performs connection admission control (CAC) functions to determine if a connection with this importance ticket value can be admitted.

Users contact ticket servers using a high priority signalling connection and provide the following information to the ticket servers to request a ticket.

- User identity
- User organizational affiliation
- User's view of the current context - This could be normal context, local emergency (i.e. E911 situations), general emergencies (e.g. tornadoes, hurricanes, bombings) and phases of disaster response.
- User work function - Normal function or some type of

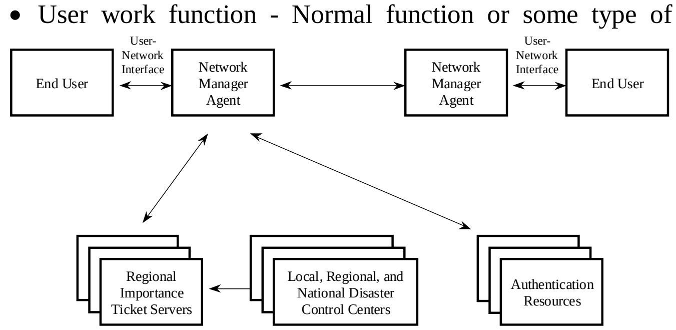

FIGURE 1 - CONNECTION IMPORTANCE ADMINISTRATION ARCHITECTURE

special activity.

- Authentication sources to contact.

If the interaction with ticket servers requires that importance or identification information be verified, the system can contact authentication resources to provide such verification.

Ticket servers are trusted, automated representatives of network operations organizations. They correlate information provided by users with their knowledge of the current network context (network overloading and failures, natural disasters, societal conditions, etc.). The most significant benefits of using this architecture are the following.

- Quick connection admission – Decision processes for issuing tickets are performed off-board at the servers, not at the switches.
- Detailed tracking of resource usage - Importance tickets allow networks to track resource usage based on connection importance levels. This provides a detailed, instantaneous view of how the network is being used and for what purposes.
- Server context models - Servers keep models of the current context that are regionally distributed and national in scope. Models can be dynamically updated through interactions with individual trusted users, groups of users who are all in agreement, other servers, network operations centers, or disaster control centers.
- Low overhead – No overhead is added to the standard admission process if users choose not to contact the servers.
- Regional deployment – Geographically distributed ticket servers allow users to contact, with high probability, at least one server to request tickets.

B. IMPORTANCE TICKETS

The purpose for using importance tickets is threefold.

1. Importance tickets supersede payment mechanisms. Even if a user can spend a large amount of money for a connection, resources cannot be taken from crisis response efforts.
2. Importance tickets are not necessary when a user does not expect special treatment from the network, causing no unnecessary network overhead.
3. Importance tickets provide an alternative to payment mechanisms for users who cannot pay for an important or emergency connection.

An importance ticket has three attributes: value, duration, and a connection identifier. The value of an importance ticket is not in dollars, but rather in a unit called an “imp”. An imp is a small integer (e.g. with a maximum value of 10) that corresponds to importance categories used by a connection admission control (CAC) process. An alternative is an "imp-t" in units of imps times time, which is used at the user's discretion according to an (imp, time) specification until the imp-t is exhausted. The duration parameter specifies a short time period until a ticket expires, and the connection identifier specifies one connection for which it can be used. Imps and pricing mechanisms are related, but, beyond a certain point, adding value to an importance ticket can only come from a further justification of the connection’s importance in the current context.

Importance tickets are similar to electronic cash in that they are a generally accepted exchange mechanism and must be securely stored and transferred. They are not similar, however, in that they expire and are not transferable. Since the value of a ticket depends on the current context, two requests for the same amount of network resources may receive very different ticket values. Advances in electronic commerce technology will be reused for security of importance tickets [4]. Business models of network providers may require that they be reimbursed for importance tickets they accept.

C. RELATED WORK

In this work, a deliberate use is made of the term *importance* instead of *priority*. Priority is used very widely in the networking community, but usually relates to queuing or congestion control mechanisms for packet level QoS (e.g. priority queuing or prioritized packet discarding). Many protocols support priority fields, including IPv6's 4-bit priority field [5], ATM's cell loss priority bit, and recent work by the IETF Differentiated Services Working Group on the DS byte [6].

Importance, on the other hand, is being used here to pertain to blocking probabilities for connection level QoS. Requests for important connections should be blocked less. Connection importance is used in today's voice network with the Telecommunications Service Priority [7] which uses static priorities within a fixed context based solely on user identity, and Multi-Level Precedence and Preemption [8] [9] in military contexts where users decide their own priority (flash, immediate, priority, or routine) within authorized limits. In contrast, this architecture dynamically determines connection importance based on the current context and does not allow users to decide their own importance but rather works with users to negotiate for tickets.

Recent research has investigated pricing mechanisms to determine connection importance [10]. Pricing mechanisms, however, cannot respond well to emergencies or cases where users have urgent needs but cannot pay. Other work has addressed signalling of importance information [11] or general management and service architectures [12], but has not dealt directly with how importance should be determined.

The use of ticket servers here is similar to that of Kerberos [13]. Intelligent agent technology has been proposed for a wide variety of telecommunications applications [14] [15] [16], most notably service provision [17] and network management [18] [19]. The work here is significant, however, because it proposes intelligent agents for signalling and connection admission control.

III. DIFFICULTIES IN DETERMINING IMPORTANCE

Even when an architecture is defined that uses importance ticket servers to assist the network in connection admission control, a greater problem still must be addressed. How do these servers decide which connections are more important than others? This question is made especially difficult by users who are new to the geographic area, network failures, and dynamic context changes.

The architecture must do the following to ensure that the decisions of servers are generally acceptable.

- Ensure that information users provide is verified.
- Provide high user satisfaction.
- Resolve differences in viewpoints between servers and users.
- Clarify misunderstood information, e.g. the use of terminology not recognized by the ticket server.
- Make correct decisions within the dynamic context and the phases of an emergency.
- Give individual users with high credibility or authority preferential treatment.

IV. DESIGN

The ticket server architecture to address the issues above is based on two basic technologies -- intelligent agents and agent communication. Agent communication provides a rich negotiation protocol, and intelligent agent technology exploits capabilities for autonomy and reasoning. An intelligent user agent provides the server with information, provides verification, requests tickets, asks for explanations, and presents new information. The ticket server intelligent agent decides on the value of a ticket. It determines if it agrees with the user's facts and determines the value of the ticket for the current context. Table 1 lists the criteria from the previous section and shows whether agent communication (AC) or an intelligent agent (IA) technology is being applied to address that issue.

TABLE 1 - CORRELATION OF AGENT COMMUNICATION AND INTELLIGENT AGENT BENEFITS TO DESIGN ISSUES

Issue	AC	IA	Discussion
Verification of Information	✓		Servers verify information by using agent communication to have users provide references to verification sources or provide verification directly.
User Satisfaction	✓		User satisfaction will primarily involve how well the server communicates to the user why it made its decisions and how it gives the user a chance to affect those decisions.
Differences in Viewpoint	✓		When the server disagrees with the user's view of the context, the user can inquire about the server's perspective and provide new information.
Misunder-stood Information	✓		Agent communication allows a user to find out what information might have been missing or misunderstood and update it.
Dynamic Context		✓	Server intelligence correlates users and groups with the current context and phases of an emergency.
Authority and Credibility		✓	Server intelligence allows users who are experts or are in positions of high authority to directly receive tickets with the value they request.

A. *INTELLIGENT AGENTS*

The ticket server architecture uses user and server processes that exhibit intelligent behavior, namely autonomy, communication ability, negotiation, and reasoning. These behaviors are widely agreed upon as being characteristics of *intelligent agents* [20] [21] [22]. User agents act in a semi-autonomous fashion to negotiate for tickets. Server agents act semi-autonomously to decide how user claims correlate with the server's view of context and how ticket values should be assigned. Disaster response organizations and network providers provide the instructions on how decisions should be made and ticket server intelligent agents carry out those decisions. Servers also perform context model updates and decide how to service user requests for explanations.

B. *AGENT COMMUNICATION*

Agent communication languages provide mechanisms based on speech acts [23] [24] [25]. Speech acts are human communication mechanisms which explicitly assert, direct, commit, permit, or prohibit actions in others [26]. Each message in an agent communication language includes an explicit designation of a speech act (e.g. assert or request) and the content related to the speech act. This project uses KQML [24] and extends it to include performatives for requesting tickets, transferring tickets, beginning a negotiation, and terminating a negotiation. KQML was chosen because of its popularity and the availability of KQML tools, rather than an analysis of it being better than other languages.

C. *COMMUNICATION MODEL*

Fig. 2 provides the communication model for the interaction of users and servers for the acquisition of importance tickets. Boxes indicate intelligent agent decision processes, while lines indicate communication interactions. The interactions could possibly be accomplished with a protocol that does not use explicit speech acts, but the wide variety of interactions that occur here make explicit speech act representations necessary. This allows for a lack of ambiguity in the communication process and a clear representation of what is occurring.

The following observations can be made about the model.

- Users first choose how to exert authority. A user can either choose to pursue negotiations as a general user or a user with high authority.
- Users can ask for explanations, provide more information or verification, or request that the server update its model. For example, a user can ask the server to update its model when the user believes an emergency has occurred. The user may then gain access based on the emergency.
- Users can ask about their verification status and provide further verification information. This verification can be provided directly by a mechanism like a digital signature or indirectly by giving the address of a trusted source.
- User satisfaction is high by allowing users to ask if servers verified their information, if servers agreed with their claims about the context, and how their request was classified. Ticket servers could even decide to always provide simple answers to some of these questions automatically.
- Differences in viewpoint are addressed by allowing users to ask about the server's agreement with the user's claims.
- Users can request that the server update its context model with other servers, or they can ask that their own information influence a change in the context model.

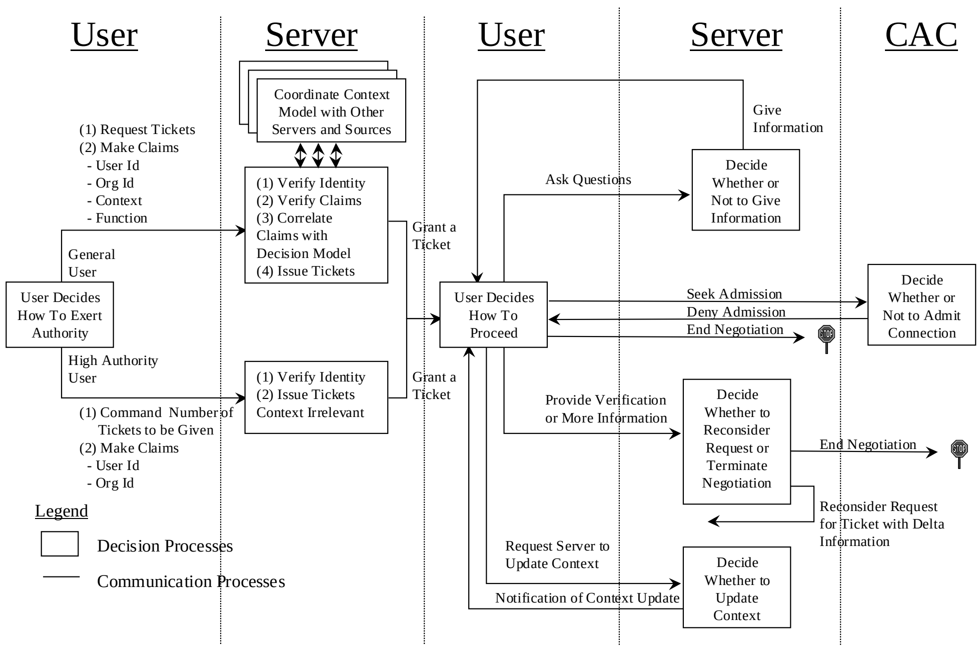

FIGURE 2 - IMPORTANCE TICKET SERVER AGENT COMMUNICATION MODEL

- A series of security issues must be addressed that are not investigated here. Solutions developed for electronic commerce would be reused here.
- Intelligent agent reasoning processes decide on the value of tickets that are issued and decide how to proceed with negotiations.

It is not intended that users know that they are satisfied simply from the value of a ticket. It is rather intended that users attempt to gain access to the network with this ticket, and then try to acquire one of higher value if their initial connection attempts are unsuccessful. A higher valued ticket is always better, however, even if access is gained to the network. If preemption is used in the network, a user would want to be more important than connections already in progress and than those that could arise in the future.

V. Benefits and Complexity

As a comparison to the ticket server communication model provided above, Fig. 3 provides an example of how ATM Signalling [27] might be extended to support traffic of different importance levels. The basic idea is that ATM connection admission control (CAC) contacts the ticket server on its own to get a ticket for the user's connection. Users do not interact with the ticket servers at all and are only given a connection acceptance or denial notification from CAC.

Many typical scenarios were considered, and the importance ticket server architecture was found to provide significant benefits, especially in the area of user satisfaction, over the extended ATM Signalling approach. Users have a greater chance for connections being admitted, greater awareness of how their connections were treated, and greater flexibility for influencing outcomes. As users like disaster response personnel find greater satisfaction and efficiency, they are more capable of performing their intended tasks well.

There are a series of issues in the implementation of an agent communication approach using ticket servers. These include the following.

- Processing of KQML agent communication.
- Implementation of immobile intelligent agents with autonomy, reasoning, and communication ability.
- Secure exchange of tickets and verification information.
- User and server decision processes about how to proceed with negotiations for tickets.
- Frivolous communication by users who misuse the ability to ask questions.
- Updating of context models.

The cost and complexity of implementing agent communication is not prohibitive compared to its benefits. Ticket servers themselves may be costly to implement, but to not use ticket servers would either greatly complicate CAC processes at switches or would remove the ability altogether to treat some traffic with greater importance. The justification for ticket servers is not addressed here, but is being investigated in related research.

VI. Conclusion

This work proceeded from the assumption that modern, integrated networks must treat some connections with greater importance than others, especially in a crisis. An importance ticket server architecture was then introduced that gave ticket servers a responsibility separate from connection admission control for determining connection importance. Users provide servers with four basic pieces of information and then servers issue tickets for gaining admission to the network.

It is proposed that users directly interact with the servers using explicit intelligent agent communication methods. Users are given flexibility to deal with common scenarios. Being able to provide verification of their claims, to find out why they received tickets as they did, and to try again for higher valued tickets is of great benefit. This work is

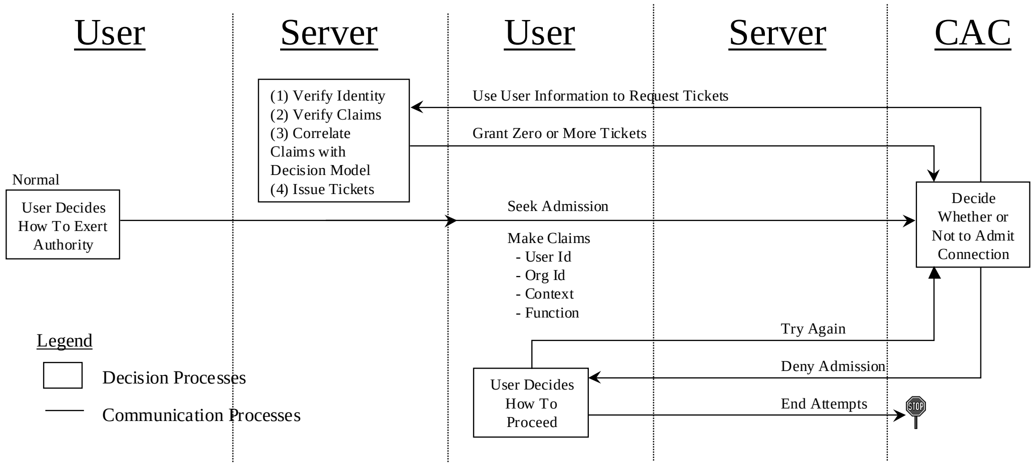

FIGURE 3 - EXTENDED ATM SIGNALLING COMMUNICATION MODEL

significant because it defines the importance of connections without relying on pricing mechanisms and applies agent communication to network connection admission control. Future work will focus on formally justifying the need for ticket servers, implementing a system prototype, and developing resource allocation mechanisms that exploit admission based on connection importance. This architecture is reasonable to implement, a viable way of determining the importance of connections, and a significant step forward in making integrated networks fully useful to the society in which they operate.

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