Presenting a New Protocol for Probabilistic Quality of Service Analysis for Distributed Control System

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ABSTRACT
There has been extensive research on design, implementation and analysis of new dedicated protocols like group protocol, feasible protocol, secure protocol etc to cater communication requirement of distributed system. However there is no predefined strategy that can be readily used for protocol selection. Performance is defined as the efficient use of resources while still meeting the applications' requirement, hence this paper provide probabilistic analysis of QoS in protocol selection. Ideal protocol features are listed in this paper. Model is design for selection criteria of protocol and creating customized QoS parameter for ease in probability analysis.

General Terms
Probabilistic Protocol, Probabilistic QoS Protocol.

Keywords
Transmission Control Protocol, Internet Protocol, Quality of Service.

1. INTRODUCTION
Distributed system are highly used in current network design to provide resource sharing, flexibility , high capacity, dynamic resource allocation as well as noise immunity [8]. Communication media as well as protocols design for distributed system has been a wide research area for exploration along with network design. Cost has also key been factor for design. Low cost distributed control system has been design with micro-controller based master slave protocol for low load networks [15]. Ring, Loop, Star bus, Star-star can be used in network architecture design where star bus with coupler provide highly reliable, simple single point of failure network[5]. Communication media preferred has been fiber optic for its higher band width capacity, electromagnetic interference protection and high reliability [5].

With the rapid development of Internet applications, high number of users, internet has formed an international collection of computer communication networks. [28]. the users of internet are no longer limited to researchers, scholars and professionals but it has opened its door for every individual. Internet can be trustworthy for same goal and single user [28]. However vulnerability of the internet can be infiltrated in the networks. This has led to developing of specialized security protocols. The security that has vulnerability in the process of design, implementation and management has been further aggravated the network un-trustworthy. Even if the network architecture has been perfectly designed Internet's vulnerability still couldn't be completely avoided in the process of software and hardware performance [27].

As the Internet has evolved as an infrastructure, so have the expectations of the users who rely on it. Once an experimental network, the Internet is now more of a commercial venture, with both casual users and paying subscribers. The merging of these communities has lead to broader quality of service (QoS) expectations of the underlying packet delivery service. With the growing mix of transports, an end-to-end QoS solution needs to understand how the various transports handle network conditions, such as congestion that leads to variable delays, and also packet loss that may or may not be congestion related

1.1 Transmission Control Protocol/ Internet Protocol

TCP/IP has been initial default choice for reliable one to one communication service [14]. The key feature of TCP is its ability to provide a reliable, bi-directional, virtual channel between any two hosts on the Internet. Since the protocol works over the IP network that provides only best-effort service for delivering packets across the network, the TCP standard specifies a sliding window based flow control[1] [3].

The initial TCP standard has a serious drawback:-

1. It lacks any means to adjust the transmission rate to the state of the network.
2. "Congestion collapse" was the second major drawback it suffers.

Various TCP variant and their congestion control mechanism are listed in the below table.

Table 1:- TCP Variants congestion mechanism

TCP Variant	Added/Changed Modes or Features
TCP Tahoe	Slow Start, Congestion Avoidance, Fast Retransmit
TCP-DUAL	Queuing delay as a supplemental congestion prediction parameter for Congestion Avoidance
TCP Reno	Fast Recovery
TCP New Reno	Fast Recovery resistant to multiple losses
TCP SACK	Extended information in feedback messages
TCP FACK	SACK-based loss recovery algorithm
TCP-Vegas	Bottleneck buffer utilization as a primary feedback for the Congestion Avoidance and secondary for the Slow Start.
TCP-Vegas+	Reno/Vegas Congestion Avoidance mode switching based of RTT dynamics.
TCP-Veno	Reno-type Congestion Avoidance and Fast Recovery increase/decrease coefficient adaptation based on bottleneck buffer state estimation
TCP-Vegas A	Adaptive bottleneck buffer state aware Congestion Avoidance

The TCP transport has evolved to be highly adaptive. It offers not only variable flow control needed between sender and receiver of a data stream, but also adaptive congestion control mechanisms. As a class of traffic on the network, TCP is therefore very well behaved. However, when mixed with other traffic over identical links, it can be too well behaved, giving up bandwidth to non-adaptive traffic.

1.2 Types of Service

We categorize the services as the following broad Type of Services classes, each having a different set of QoS parameters. Within each type of service different Quality of Services are available by adjusting the QoS parameters.

1. Real Time Service (RT)

Services that have critical tight upper bound on the time at which the bits are arrive and discard any data that are arrived beyond Expected time of Arrival (ETA). Packets delayed are of no use to the users. Examples of such services are Telephony, Teleconferencing and covering ATM.

2. Adjustable Real Time Service (ART)

In this service class, we do not discard data if it is delayed. Instead, the ETA is adjusted as long as the occurrences and durations of these delays and discontinuations are within some acceptable bounds. For example, half-duplex video may be resumed after a little pause due to the delay in packets arrival. In this case we can adjust the Acceptable Delay parameter to be increased by the stalled time. Examples of such services are Video on Demand, Video, Interactive Games, and Distance Learning.

3. Non Real Time Service (NRTS)

It includes services without QoS guarantees, which exploits available resources. Examples of such service are traditional email and File Transfer.

QoS Parameters: Translates to

Packet Delay = Delay
Delay Jitter → Delay
Packet Rate = Packet Rate
Packet Loss Probability → Packet Rate
Mean Packet Size = Packet Size
Distance (Avg. Hop Count) = Distance

The treatment of QoS parameters where "=" means the particular parameter is used as-is and "→" means that the parameter at right-hand side is transformed into the parameter in left-hand side. **Delay Jitter → Delay.** Jitter is removed by the use of play-out buffers, which introduces increase in the end-to-end Delay. In other words, Delay Jitter is reduced into an increase in the end-to-end Delay as follows: Revised Delay = Acceptable Delay +Acceptable Delay Jitter.
Packet Loss Probability → Packet Rate

2. RELATED WORK

The Real-time Transport Protocol (RTP) is an end-to-end protocol designed to accommodate data delivery for real-time applications, such as packet audio or video [RTP96]. RTP provides mechanisms, such as timestamps and sequence numbers, to enable timely and reliable delivery of real-time data, but does not guarantee services. Like TCP, Scalable Reliable Multicast (SRM) builds reliability on an end-to-end basis and adjusts control parameters based on observed network performance. However, SRM avoids TCP's sender-based approach to loss detection and recovery. The Link Level Resource Management Protocol (LLRMP) was designed to reserve resources in shared medium and bridged or switched LANS [LLRMP96] [30] Analyses TCP limitation in performance. Analysis shows 3 types of issues to be resolved in order to enhance the performance.

1. A bad choice of the acknowledgement strategy.
2. A bad choice of the time-out values.
3. Limitations due to the lack of congestion control algorithms.

[30] Paper describes high performance protocol architecture for efficient implementation of multimedia application based on Application level framing.
[2]Paper uses MODBUS over TCP for peripheral communication in industrial process plant to solve communication and compatibility problem.
[10] Paper analyses RT net in distributed real time network protocol to be used on fully connected LAN with broadcast capability and guarantee QoS, Non- real time traffic support

and Fault tolerance as main goal. [14] Analyses Flexible group communication protocol for distributed system to provide QoS in message lost and unexpected delays due to congestion and fault condition by analyzing three QoS Parameter bandwidth, message loss ratio and delay time. Flexible group protocol which can dynamically support types and quality (QoS) of service required by applications even if QoS supported by the underlying network is changed. [19] Paper analyses TRUMP- A FAST reliable transport protocol for distributed system by providing selective acknowledgment and retransmission, Variable acknowledgment rates, by having the receiver acknowledge a group of data fragments and other features to improvise QoS. TRUMP provides three qualities of service: unreliable burst communications, real-time communications and reliable communications. In the unreliable burst mode, the receiver does not return acknowledgments to the sender it does so in the other two modes. TRUMP employs rate-based flow control to match the output rate of the sender with the input rate of the receiver.
[22] Analyses Extreme transport protocol (XTP) to support new functionalities such as electronic mail, real-time transactions, image transmission, multimedia, and teleconferencing.

3. NEED FOR PROTOCOL

Protocol designs prior were for generic transport and not specialized for distributed environment. Specialized distributed protocols were designed for various domains like security, real time, group communication etc [22]. There need one generic protocol that can suit every purpose and can be customized as per requirement. Secondly QoS analysis become tedious of each network, hence defining generic QoS library as described in section 4.4 for distributed system, analysis is made ease.

4. PROTOCOL MODEL

4.1 Designing for ideal distributed protocol

Individual protocols were designed to satisfy user and network requirement. Figure 1 shows design strategy for till date protocols. E.g. Delegate protocol designed for proxy system. For new proposed protocol, the design strategy is modified as shown in figure 3.

Modified design strategy is as below:-

1. Create Main Master library with all the parameters and functions listed in QoS Library List set to default values and default probability. Refer section 4.4
2. For particular protocol / protocols requirement create independent classes (in C++) that cater each special requirement of the protocol/ protocols.
3. Select the best suited library functions along with its individual probability parameters for the desired protocol else all the default parameters, probabilities and functions to be use.
4. Main application can access the QoS main master library as well as customized library functions for specialized protocols from special protocol config file as shown in figure 4.

4.2 System Model

A group of multiple application processes A_1, A_2 and A_n as shown in figure 2 can interact among its group as well access flexible web service group by exchanging messages. The underlying network is modeled to be a collection of bi-directional logical communication channel.

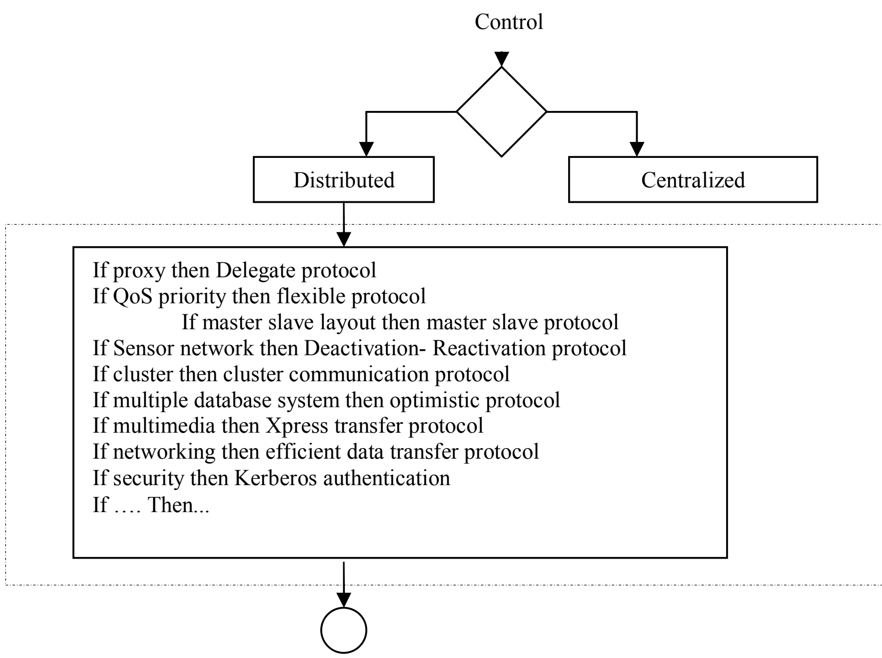

Figure 1: - Initial design strategy

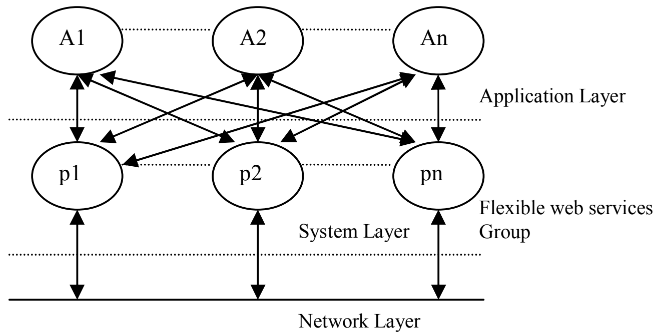

Figure 2: - System Model

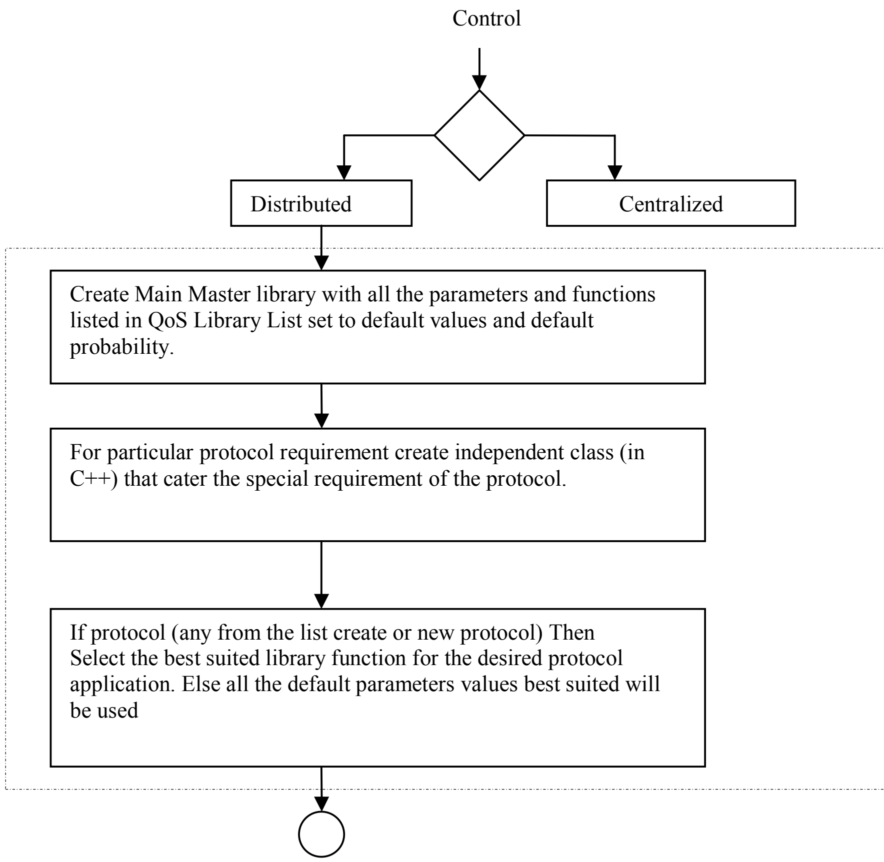

Figure 3: - Modified design strategy

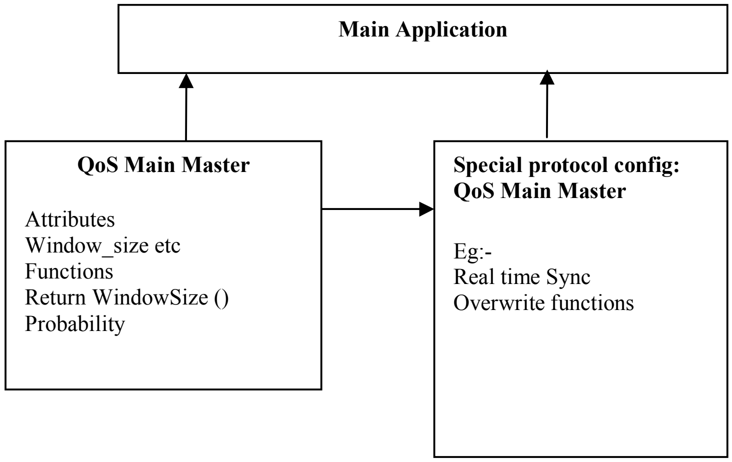

Figure 4:-High level representation of new protocol model

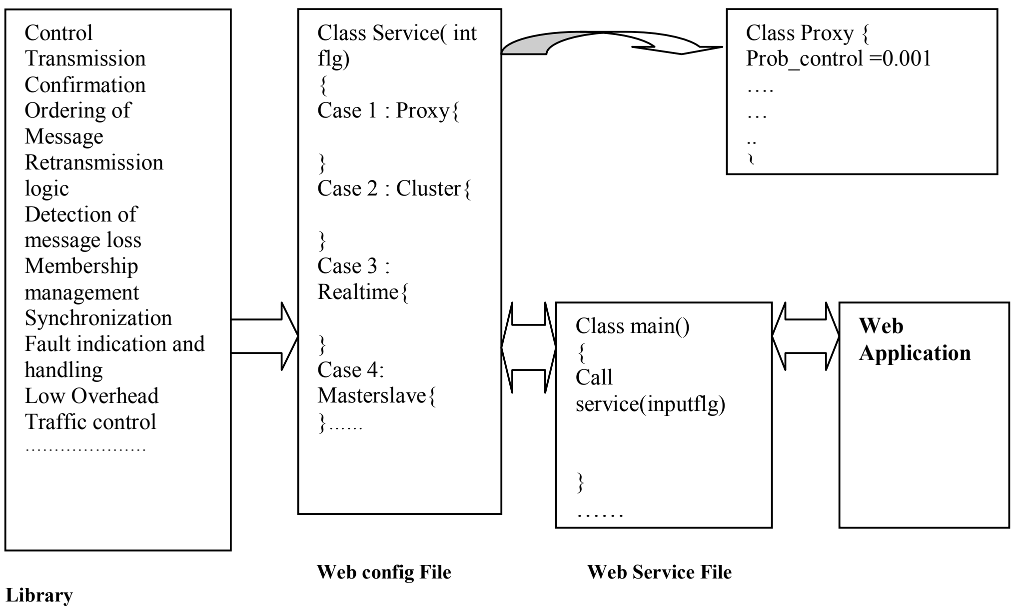

Figure 5:-Diagrammatical representation of new protocol model

4.3 Probability Model

Each element type in the library is allocated with a probability as per the system requirement. If system is real time high probability will be given to real time parameters initially and rest of the parameters will be of low probability or set to zero.

New protocol needs to support all the QoS parameters hence all elements of QoS library will be equal probable initially. As per the usage, new probability will be calculated by Probability function of main class in Web Service file as shown in Figure 5 for each library parameters. Section 4.4 details about quality library function supported in figure 5. State 0 is initial stage and state 1 to 21 is 21 QoS parameters listed in section 4.4. Default value of probability for each QoS parameter is 0.048 i.e. 1/21. Probability function shown in figure 5 updates this probability as per usage. Detail analysis of QoS library as in section 4.5

4.4 Quality of Service Library for new protocol to support

1. Control
2. Transmission
3. Confirmation
4. Ordering of Message
5. Retransmission logic
6. Detection of message loss
7. Membership management
8. Synchronization
9. Fault indication and handling
10. low Overhead
11. Traffic control
12. Bandwidth Utilization control
13. Flow control

14. Dynamic fragmentation
15. Acknowledgement rate configuration
16. Window size configuration
17. Selective acknowledgement
18. Retransmission in group communication
19. Multiple messages per group if message to same destination
20. Selective acknowledgement for non- group
21. Selective retransmission for non- group
22. Activation – Reactivation timer set
23. Other Parameters

4.5 Analysis of QoS Library

QoS library can be represented as stochastic process with random parameters selection from state space of X as collection of random quality variable.

Expected value of each QoS Parameter(X1, X2... Xn) is given by

$$E(X) = \int xdp \ldots\ldots\ldots (1)$$

$$= \sum_{i=1}^{n} \alpha i \; P[Ai] \ldots\ldots\ldots (2)$$

Where x is individual sub-element of QoS Parameter (X)
αi = Weighting factor of each probability element.
$P[Ai]$ = probability of individual quality element.

Probability Model as shown in figure 6 can be expressed in Markov chain. A Markov chain for independent QoS properties X1, X2, X3 ...Xn is given by below formula.

$$Pr\,(X_{n+1} = x | X_1 = x_1,\, X_2 = x_2 \ldots X_n = x_n)$$
$$= Pr\,(X_{n+1} = x | X_n = x_n) \quad \ldots\ldots\ldots (3)$$

The probability of going from state i to state j in n time steps is

$$P_{ij}^{(n)} = Pr\,(X_n = j \mid X_0 = i) \quad \ldots\ldots\ldots (4)$$

And the single-step transition is

$$P_{ij} = Pr\,(X_n = j \mid X_0 = i) \quad \ldots\ldots\ldots (5)$$

A sequence of random variable Xn converges in probability to a random variable X if for ε>0

$$\lim P[|Xn - X| >= \varepsilon] = 0 \ldots\ldots\ldots (6)$$

Example: If timely delivered packet X consist of various factors {zero delay, timely acknowledgement etc} then X1 = zero delay, X2= timely acknowledgement till Xn.
Then

$$\lim_{n\to\infty} P[|Xn - X| >= \varepsilon] \ldots\ldots\ldots (7)$$

Equation 7 is called stochastic convergence.

5. CONCLUSION

Protocol design varies for implementation to implementation, hence selection of right QoS Parameter is a trade of between timely and correctly delivery of data. Probability analysis clearly defines that property behaves Markov chain property hence independently. One timely delivery of packet does not assure next delivery to be of same QoS. For periodically these parameters has to be analyze to keep QoS in check. QoS Library being dynamic can be configured periodically to add or delete unwanted parameters.
QoS also depends on the web-service that implements it, hence network traffic or break down can affect QoS calculation. Hence QoS becomes relative term with respect to implementation.
This paper has made an effort to create dynamic QoS library for protocol and customizing QoS Parameter as per user need and hence minimizing efforts required in creating new protocol for individual need.

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