The Use of Fuzzy Metric in QoS Based OSPF Network

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Abstract: The use of a single metric for adaptive routing is insufficient to reflect the actual state of the link. In general, there is a limitation on the accuracy of the link state information obtained by the routing protocol [1, 2], as the accuracy of the metric is usually predetermined by the network state update interval [3]. Hence it becomes useful if two or more metrics can be associated to produce a single metric that can describe the state of the link more accurately. And this paper investigates how two metrics, the mean link utilisation and the mean link delay, can be related using a simple fuzzy logic algorithm to produce a fuzzy metric that is more 'precise' than either of the single metric.

1. Introduction

QoS routing is one of the tools available to network operators to improve their ability to handle traffic with specific requirements, for example high throughput and low delay. With the flexibility of OSPF, it is possible that traffic can be routed based on the concept of type of service (TOS), such as maximise throughput (TOS 8) and minimise delay (TOS 16). However, what is found wanting in these classes is that each of them uses a distinctively different routing metric and neither of these metrics is inferable from each other. The 2 metrics use separate rules for defining the best route, for example delay uses an additive rule and throughput uses convex rule for defining the best cost route. Hence a clear method to associate these 2 metrics to produce a single metric will be useful for QoS routing. In this paper, a proposed method would be to use fuzzy logic in order to associate mean link delay and mean link utilisation to produce a single crisp metric, namely the congestion level.

2. The 2 complementing metrics

The delay along a route can be estimated by summing the individual link's delay. However, a lower delay along a particular route compared to other possible routes does not necessarily mean that this particular route have the most available bandwidth. Hence, intuitively, link utilisation would be a useful association with link delay in deriving the single metric. What proves to be valuable is that link delay can complement the inadequacy of link utilisation too! Link utilisation has its limitation in describing how 'congested' the link. The burstiness of data traffic as well as the presence of buffering causes the link utilisation distribution to no longer exhibit a normal distribution when link capacity is approached. This means that queueing can occur even when mean link utilisation is below the link capacity. Link delay, being comprised of the queueing delay and propagation delay, would then complement link utilisation in representing the state of the link. Note though that the proportion of queueing delay to that of propagation delay will affect the size of the link delay.

3. Fuzzy Logic

Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth – true values between "completely true" and "completely false". It was introduced by Dr. Lotfi Zadeh of U.C. Berkeley in the 1960's.

The use of fuzzy logic to describe the state of a link mimics how a person makes a decision, but only much faster. Fuzzy logic incorporates a simple, rule based IF X AND Y THEN Z [4] approach to decide on the congestion level rather than attempting to model the traffic characteristics mathematically. The fuzzy logic model is empirically-based, relying on one's network experience rather than detailed understanding of traffic characteristics. For example, rather than dealing with percentage mean link utilisation > 80% or percentage mean link delay > 75%, rules like "IF (mean link utilisation is high) AND (mean link delay is high) THEN (link congestion level is high)", or "IF (mean link utilisation is medium)

AND (mean link delay is low) THEN (link congestion level is low)". Using non-numerical terms is imprecise and yet very descriptive of how congested the link is. Therefore, fuzzy logic is essentially a computational method that can be used to associate different metrics so as to produce a crisp value that can describe the link state whilst being fast and accurate. The diagram below shows the fuzzy system that has been designed to predict link congestion (Fuzzy centroid algorithm is used in the defuzzification process):

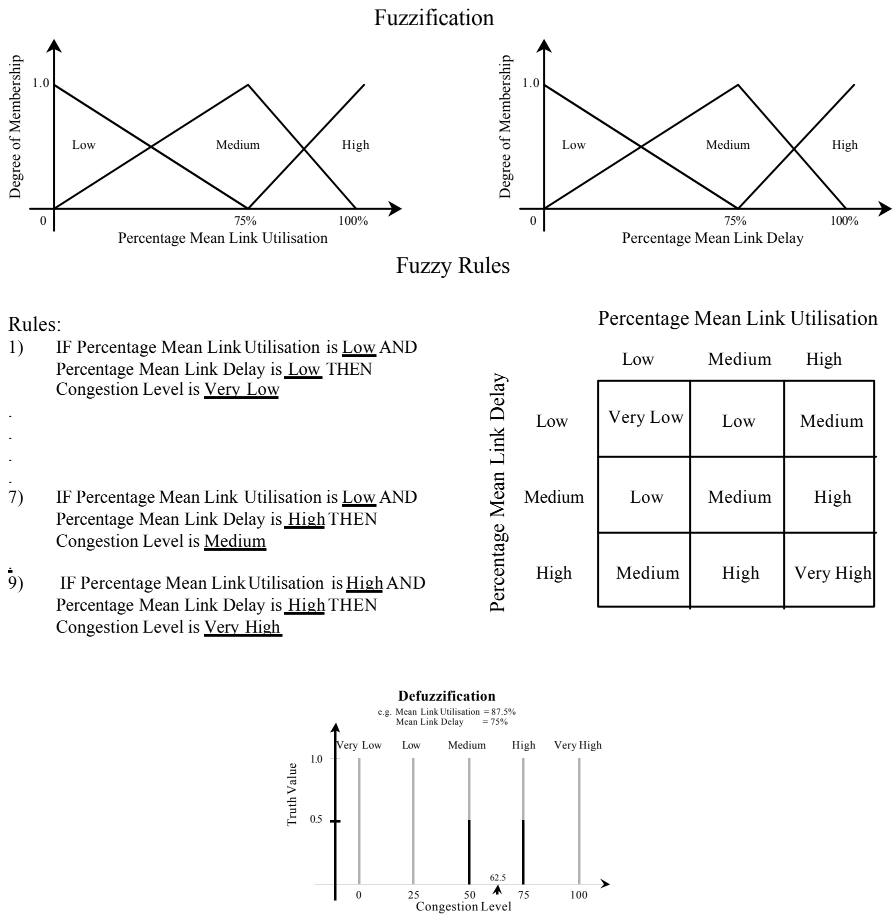

Figure 1. Fuzzy inference process

4. Discussion

An important aspect about the fuzzy congestion level, derived using the above fuzzy logic algorithm, is that the metric is partitioned into two halves. Effectively, the congestion level can only reach a maximum of 50% if the mean link delay is 0% and vice versa (only an association of both metrics with non-zero values will allow them exceed the 50% boundary). This means that while using only the mean link delay as the routing metric will not reflect the bandwidth usage of a link (because of no queueing), the fuzzy metric will be able to take into account the link bandwidth usage and provide a best route that is less congested and with possibly minimum delay. The plots in Figures 2 and 3 are able demonstrate this. The main assumptions of the experiments are:

1) queueing delay is the more important factor to differentiate between delay on different links, as propagation delay is always constant;
2) an average packet size is assumed in computing the maximum queueing delay;

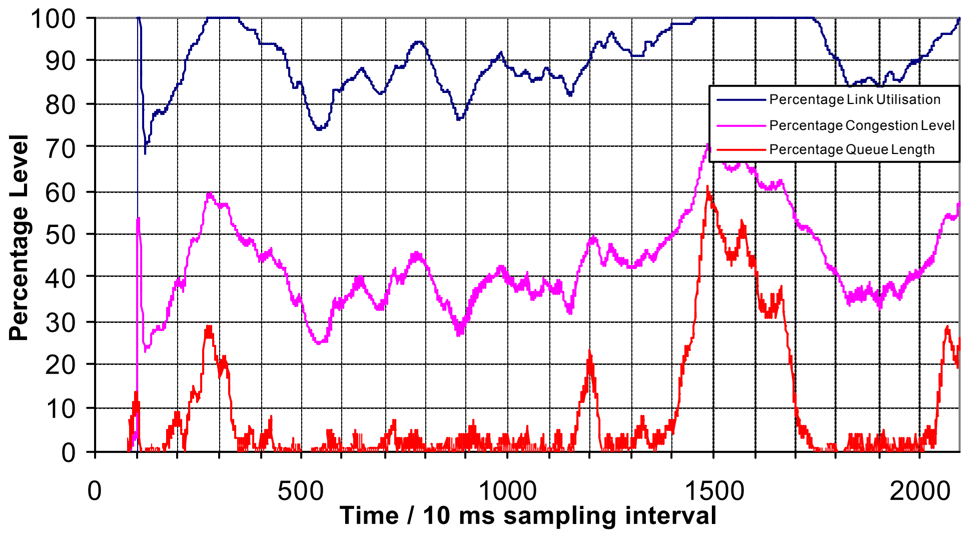

Figure 2. Trace of defuzzified metric with respect to mean link utilisation and mean link delay

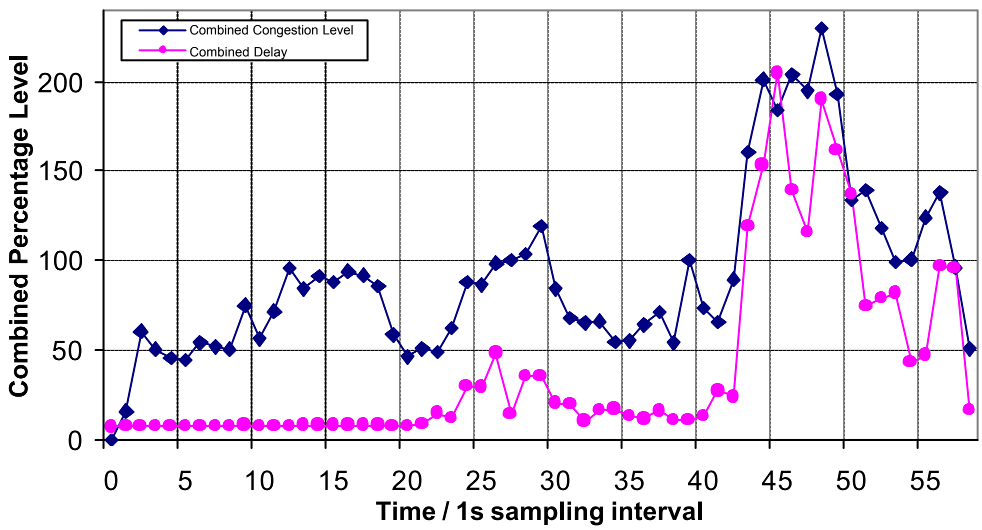

Figure 3. Sum of metrics along a route comprising of 3 links

Another important point that is demonstrated in Figure 3 is that the sum of fuzzy metric is able to trace the sum of delay along a route fairly closely. This implies that, for an OSPF network, there is less complication if this fuzzy metric is implemented. However, the main reason for using the fuzzy metric as an additive metric is that the fuzzy metric emphasises more on the link delay rather than the link utilisation. If the fuzzy metric is computed using a convex rule, it is unlikely that the computed path will produce a significant metric.

The reason that more weights are given to HIGH mean link utilisation and High mean link delay, as shown in Figure 1 in their respective membership function, is so that the congestion level value will change more than other combinations of inputs, hence emphasising the importance of such states. This, on the other hand, has the implication that the sum of fuzzy metric along a route that comprises of links with either of these 2 HIGH metric value will be significantly increased, making it less favourable than it is otherwise. This also has the benefit that if threshold based updates policy [3] is employed in triggering link state updates, updates will then only more likely be triggered if the high 'congestion' region is reached, hence possibly reducing the protocol overhead cost.

5. Conclusion

The incentive of using this fuzzy metric for obtaining 'better' routing decision is clear, given the extra dimension that this metric is able to offer. However, the major drawback about using this single value to represent 2 metrics is that the single value will lose distinct information about each of the 2 metrics. But since routing metric is itself inaccurate in the first place, it might justify using this fuzzy metric, instead of delay alone, to find the 'best' route with possibly the lowest delay and with more available bandwidth.

6. Future work

After demonstrating the attractiveness of the fuzzy metric, this metric will need to show its significance over normal OSPF in terms of relieving congestion and providing QoS to specific traffic, such as those which require low delay and loss packet loss (Differentiated Service, DiffServ), before they should be considered deploying across the OSPF network. In particular, the comparison with OSPF that uses delay metric in terms of delay minimisation, stability optimisation and packet loss minimisation under different load conditions and network topologies will be of great importance.

7. Acknowledgements

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8. References

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