QUALITY OF SERVICE OPTIMIZATION IN MANET USING FUZZY QUEUES

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ABSTRACT

In mobile Ad hoc networks Data transmission need high bandwidth and reliable transfer because of large amount of data size and frequent path break due to mobility. When the Quality of Service metrics (Qos) in ad hoc networks is improved, longevity of the network increases. Selecting suitable microcontroller and wireless transceiver chips play an important role in assembling ad hoc mobile devices, in which data control should be designed, so that packet loss is minimized. Available Qos metrics based on Queuing or buffer management in wired and other wireless networks don’t applicable in Ad hoc networks because of its unique characteristics. In this paper the simplest Qos model buffer less system were proposed. So far many researchers have taken crisp data for packets arrival rate. But in real time, the values of the parameters are vague. To overcome this ambiguity, we take the arrival rate of packets as trapezoidal fuzzy number. Because of taking arrival rate as a fuzzy parameter, the results of system characteristics are more realistic in nature. In this paper, measurement of the fuzzy probability of blocking of the arrival packets was suggested by using Queuing theory with fuzzy arrival rate to improve Qos. Finally defuzzify the fuzzy probability of blocking by using robust ranking technique which is useful for system designers. Numerical example is given to check the validity of the proposal.

Keywords: Ad hoc networks, QoS, fuzzy sets, trapezoidal fuzzy number, series queue with blocking probability, robust ranking technique.

1. INTRODUCTION

In this paper we have discussed mobile ad hoc networks with fuzzy Queuing Systems. Adhoc means “Arranged or happening when necessary and not planned in advance”. Ad hoc networks are widely investigated area in the last two decades. Mobile Ad hoc Network (MANET) consists of limited power, limited memory and wirelessly connected devices such as cell phones, laptops, Personal Digital Assistants, wearable or handheld digital devices. These devices are dynamically self organized mobile nodes deployed in a distributed fashion with no pre existing infrastructure.

Ad hoc networks provide much more flexibility because they enable devices to move freely between various networks. Generally there are many implementations, one of them is Bluetooth (for example, the devices include mobile phones, printers, cameras, laptops, tablets) used for instant communication i.e. to create the highly secured ad hoc network and fast data transmission but limited to communication range in short span. The another one widely used is laptop which is equipped with wireless PCI cards, it establishes an Ad hoc network by activating AD-HOC MODE. This proves highly useful for business meeting where no infrastructure available and completely put an end to the necessity of Cables and Routers.[1]

Additionally, Military operations or after environment disaster it is essential to provide speedy communication. Furthermore it is highly probable that the existing infrastructure is being destroyed. These kind of situations can be dealt with ad hoc networks due to its quick deployment [2]. Even though there are some issues to be focused. Mainly data dropping Play a vital role in data transmission. In Real time, delay sensitive applications such as Tsunami monitoring, nuclear plant radiation monitoring, border surveillance, forest fire monitoring like disaster prone areas become more vulnerable due to packet dropping. To overcome these kind of problems, here we used Quality of Service (QoS) metrics with the help of fuzzy Queuing System.

In this paper, we assume packet arrival rate is trapezoidal fuzzy number which is much more realistic than the crisp values. When data transmission packets are blocked due to congestion. To overcome this problem, we have found fuzzy blocking probability and it will be reduced by increasing the service rate. Then using robust ranking technique fuzzy probability has been converted in to crisp values which is very useful for system designers. Because of reducing blocking probability, QoS will be increased and hence packet dropping will be considerably reduced.

2. Series Queue with blocking in the Processor Memory
In MANETs QoS metrics play an important role to reduce the energy consumption. In Figure 1 The processor memory is divided into two parts as separate service channels. The MAC sub layer has been determined as one server with service rate \( \mu_2 \) and rest of the network layers were taken as a one server with service rate \( \mu_1 \). Arrival packets enter the MAC sub layer through the physical medium (physical layer) and waits in the queue if the system is busy[8],[9]. In this paper we have taken buffer less system and have shown the Quality of Service metric on fuzzy arrival rate.

Let \( P(x) \) denote steady state probability of state \( x \).

Then balance equation for these five states are given by

\[
\begin{align*}
\mu_2 P(0,0) &= \mu_2 P(0,1) \\
\mu_2 P(1,0) &= \mu_2 P(0,0) + \mu_2 P(1,1) \\
(\lambda + \mu_2) P(0,1) &= \mu_2 P(1,0) + \mu_2 P(0,1) \\
(\mu_1 + \mu_2) P(1,1) &= \lambda P(0,1) \\
\mu_2 P(0,1) &= \mu_2 P(1,1) 
\end{align*}
\]

Since the process has to be in any one of the 5 mutually exclusive and exhaustive states, we have

\[
P(0,0)+ P(1,0)+ P(0,1)+ P(1,1)+ P(b,1) =1
\]

The traffic intensities for the entire queuing system, service point 1, service point 2 are defined as

\[
\rho = \frac{\lambda}{\mu_1} = \frac{\lambda}{\mu_2} = \frac{\lambda}{\mu_2} = \frac{\lambda}{\mu_2} \text{ Respectively.}
\]

Here we consider the Probability of blocking as a QoS metric.

Since arrival rates are trapezoidal fuzzy numbers, we calculate fuzzy probability of blocking for two cases.

1) \( \mu_1 = \mu_2 \)
2) \( \mu_1 \neq \mu_2 \)

In this model Probability of blocking occurs if the first server is busy or the state is blocking.

i.e FPB= \( P(1,0)+ P(1,1)+ P(b,1) \)
CASE 1: \( u_1 = u_2 \)

\[
\text{FPB} = \left( \frac{b_2 - a_1}{a_2 - a_1} \right) P(0,0), \quad \text{Where} \quad P(0,0) = \left( 1 + \frac{b_2 - a_1}{a_2 - a_1} \right) \]

CASE 2: \( u_1 \neq u_2 \)

\[
\text{FPB} = \left[ 1 + \left( \frac{b_2 - a_1}{a_2 - a_1} \right) \right] P(0,0), \quad \text{Where} \quad P(0,0) = \left[ 1 + \left( \frac{b_2 - a_1}{a_2 - a_1} \right) \right]^{-1}
\]

3. Fuzzy arithmetical operations under function principle


3.1. Definition

A fuzzy set is characterized by a membership function mapping elements of a domain space or universe of discourse \( X \) to the unit interval \([0,1]\), i.e., \( \mu : X \rightarrow [0,1] \). Here, \( \mu : X \rightarrow [0,1] \) is a mapping called the degree of membership function of the fuzzy set \( A \) and \( \mu(x) \) is called the membership value of \( x \in X \) in the fuzzy set \( A \). These membership grades are often represented by real numbers ranging from [0,1]

3.2. Definition

A fuzzy set \( A \) of the universe of discourse \( X \) is called a normal fuzzy set implying that there exist at least one \( x \in X \) such that \( \mu(x) = 1 \).

3.3. Definition

The fuzzy set \( A \) is convex if and only if, for any \( x_1, x_2 \in X \), membership function of \( A \) satisfies the inequality

\[ \mu_A \left( \lambda x_1 + (1-\lambda) x_2 \right) \geq \min \{ \mu_A (x_1), \mu_A (x_2) \} \quad 0 \leq \lambda \leq 1 \]

3.4. Definition: (\( \alpha \)-cut of a trapezoidal fuzzy number)

The \( \alpha \)-cut of a fuzzy number \( A(x) \) is defined as

\[ A(\alpha) = \{ x : \mu(x) \geq \alpha, \alpha \in [0,1] \} \]

3.5. Definition (Trapezoidal fuzzy number)

For a trapezoidal number \( A(x) \), it can be represented by \( A(a,b,c,d) \) with membership function \( \mu(x) \) is given as,

\[
\mu(x) = \begin{cases} x-a & a \leq x \leq b \\ 1-b & b \leq x \leq c \\ c-a & c \leq x \leq d \\ 0, \text{ otherwise} \end{cases}
\]

3.6. Function principle

Function principle is proposed to be as the fuzzy arithmetical operations by trapezoidal fuzzy numbers. We describe some fuzzy arithmetical operations under Function Principle as follows[3],[6].

Suppose \( \tilde{A} = (a_1, b_1, c_1, d_1) \) and \( \tilde{B} = (a_2, b_2, c_2, d_2) \) are two trapezoidal fuzzy numbers. Then

(i) Addition of two fuzzy numbers \( \tilde{A} \) and \( \tilde{B} \) is defined as

\[ \tilde{A} \oplus \tilde{B} = (a_1 + a_2, b_1 + b_2, c_1 + c_2, d_1 + d_2) \]

where \( a_{12}, b_{12}, c_{12}, d_{12} \) are any real numbers.

(ii) Multiplication of two fuzzy numbers \( \tilde{A} \) and \( \tilde{B} \) is defined as

\[ \tilde{A} \otimes \tilde{B} = (a_1 a_2, a_1 b_2, a_1 c_2, a_1 d_2) \]

where \( a_{12}, b_{12}, c_{12}, d_{12} \) are any positive real numbers.
(iii) Division of two fuzzy numbers $A$ and $B$ is defined as

$$A \div B = \left( \frac{a_1}{b_1}, \frac{a_2}{b_2}, \frac{a_3}{b_3}, \frac{a_4}{b_4} \right)$$

where $a_1, b_1, a_2, b_2, a_3, b_3, a_4, b_4$ are any positive real numbers.

(iv) Scalar Multiplication

Take $\alpha$ be any real number. Then for $A \geq 0$, $\alpha A = (\alpha a_1, \alpha b_1, \alpha a_2, \alpha b_2, \alpha a_3, \alpha b_3, \alpha a_4, \alpha b_4)$

(v) The inverse of a fuzzy number $A = (a_1, b_1, a_2, b_2, a_3, b_3, a_4, b_4)$ is defined as $A^{-1} = \left( \frac{1}{a_1}, \frac{1}{b_1}, \frac{1}{a_2}, \frac{1}{b_2}, \frac{1}{a_3}, \frac{1}{b_3}, \frac{1}{a_4}, \frac{1}{b_4} \right)$

where $a_1, b_1, a_2, b_2, a_3, b_3, a_4, b_4$ are any positive real numbers.

4. Robust Ranking Technique – Algorithm

Using robust ranking technique fuzzy numbers can be converted into crisp ones. Robust ranking technique which satisfies compensation, linearity, and additive properties and provides results which are consistent with human intuition. Give a convex fuzzy number $\tilde{a}$, the Robust Ranking Index is defined by

$$R(\tilde{a}) = \int_0^1 0.5(a_3 - a_1)da$$

where $\tilde{a} = (a_1, a_2, a_3, a_4)$ is the $\alpha$-level cut of the fuzzy number $\tilde{a}$. [5]

In this paper we use this method for ranking the fuzzy numbers values. The Robust ranking index $R(\tilde{a})$ gives the representative value of the fuzzy number $\tilde{a}$. It satisfies the linearity and additive property.

5. Numerical example

5.1 Suppose service rates at the two service points are equal i.e. $\mu_1 = \mu_2$

Assume the arrival rate $\lambda = (1, 2, 3, 4)$ and $\mu_1 = \mu_2 = 30$

Fuzzy Probability of blocking (FPB) = $R(\tilde{a})$

$$\rho = \frac{\tilde{a} - \tilde{b}}{\tilde{a} + \tilde{b}} = \left( \frac{0.093, 0.098, 0.122, 0.138}{0.093, 0.098, 0.122, 0.138} \right)$$

Where $P(0.0) = (1 + 2 - 2 \rho - \frac{\rho^2}{2})^{-1} = (1 + 2(0.093, 0.098, 0.122, 0.138) + 1.5(0.093, 0.098, 0.122, 0.138)^{-1})^{-1}$

$P(0.0) = (1, 0.093, 0.122, 0.138)$

FPB = $[0.093, 0.098, 0.122, 0.138] \div [0.774, 0.823, 0.878, 0.937]$ (0.027, 0.06, 0.1, 0.149)

Proceeding similarly we can calculate fuzzy blocking probability for all fuzzy arrival rate $\tilde{a}$ as follows:

<table>
<thead>
<tr>
<th>Fuzzy arrival rate $(\tilde{a})$</th>
<th>Fuzzy Probability of Blocking when $\mu_1 = \mu_2 = \mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\mu = 30$</td>
</tr>
<tr>
<td></td>
<td>$\mu = 35$</td>
</tr>
<tr>
<td></td>
<td>$\mu = 40$</td>
</tr>
<tr>
<td>(1, 2, 3, 4)</td>
<td>(0.027, 0.06, 0.1, 0.149)</td>
</tr>
<tr>
<td></td>
<td>(0.023, 0.052, 0.086, 0.126)</td>
</tr>
<tr>
<td></td>
<td>(0.02, 0.046, 0.075, 0.109)</td>
</tr>
<tr>
<td>(6, 7, 8, 9)</td>
<td>(0.149, 0.192, 0.24, 0.297)</td>
</tr>
<tr>
<td></td>
<td>(0.134, 0.169, 0.21, 0.25)</td>
</tr>
<tr>
<td></td>
<td>(0.119, 0.151, 0.186, 0.225)</td>
</tr>
<tr>
<td>(11, 12, 13, 14)</td>
<td>(0.251, 0.297, 0.35, 0.409)</td>
</tr>
<tr>
<td></td>
<td>(0.226, 0.226, 0.31, 0.36)</td>
</tr>
<tr>
<td></td>
<td>(0.206, 0.24, 0.278, 0.321)</td>
</tr>
<tr>
<td>(16, 17, 18, 19)</td>
<td>(0.334, 0.381, 0.435, 0.495)</td>
</tr>
<tr>
<td></td>
<td>(0.305, 0.345, 0.392, 0.44)</td>
</tr>
<tr>
<td></td>
<td>(0.279, 0.316, 0.355, 0.398)</td>
</tr>
<tr>
<td>(21, 22, 23, 24)</td>
<td>(0.403, 0.451, 0.503, 0.559)</td>
</tr>
<tr>
<td></td>
<td>(0.37, 0.411, 0.458, 0.507)</td>
</tr>
<tr>
<td></td>
<td>(0.342, 0.379, 0.419, 0.462)</td>
</tr>
</tbody>
</table>
Using Robust Ranking Indices for the trapezoidal fuzzy numbers, we calculate the crisp values for the fuzzy probability of blocking.

i.e. The \( \alpha \)-cut of the fuzzy number \((0.027, 0.06, 0.1, 0.149)\) is \((\alpha a_1, \alpha a_2, \alpha a_3, \alpha a_4)\) where \(\alpha a_i = (0.027 + 0.033\alpha, 0.06 + 0.133\alpha, 0.1 + 0.06\alpha, 0.149 + 0.049\alpha)\)

\[ R(\alpha) = \int_0^\infty 0.5(0.170 - 0.010\alpha) \, d\alpha = 0.5 \left[ \frac{1}{2} \alpha (0.170 - 0.010\alpha)^2 \right]_0^{0.084} = 0.5 \times 0.084 \]

Proceeding like this we can calculate all the values.

Table 2

<table>
<thead>
<tr>
<th>Fuzzy arrival rate ((\lambda))</th>
<th>Probability of Blocking when (\mu = 30)</th>
<th>Probability of Blocking when (\mu = 35)</th>
<th>Probability of Blocking when (\mu = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1,2,3,4)</td>
<td>0.084</td>
<td>0.071</td>
<td>0.062</td>
</tr>
<tr>
<td>(6,7,8,9)</td>
<td>0.219</td>
<td>0.190</td>
<td>0.170</td>
</tr>
<tr>
<td>(11,12,13,14)</td>
<td>0.326</td>
<td>0.288</td>
<td>0.261</td>
</tr>
<tr>
<td>(16,17,18,19)</td>
<td>0.411</td>
<td>0.370</td>
<td>0.337</td>
</tr>
<tr>
<td>(21,22,23,24)</td>
<td>0.479</td>
<td>0.436</td>
<td>0.400</td>
</tr>
</tbody>
</table>

5.2 Suppose service rates at the two service points are not equal (i.e \(\mu_1 \neq \mu_2\)) i.e \((\mu_2 > \mu_1)\)

Assume the arrival rate \(\lambda = (1,2,3,4)\), \(\mu_1 = 30\)

Fuzzy Probability of blocking (FPB) = \((\frac{\mu_1}{\mu_1} + \rho)\)P(0,0)

\[ \rho = \frac{1}{\mu_1} (\frac{\mu_1}{\mu_1} + \frac{\mu_2}{\mu_2}) = \left( \frac{0.033, 0.006}{0.1, 0.133} \right) \]

Where \(P(0,0) = \left( 1 + \frac{1}{2 \rho + \frac{\rho^2}{2}} \right) = \left( 1 + 2 (0.083, 0.006, 0.1, 0.133) \right)^{-1} + 1.5 (0.001, 0.000, 0.01, 0.017)^{-1} \)

\[ P(0,0) = (0.786, 0.834, 0.886, 0.942) \]

PB\((0.027, 0.061, 0.098, 0.137)\) \((0.786, 0.834, 0.886, 0.942)\)\(= (0.023, 0.052, 0.087, 0.131)\)

Proceeding similarly we can calculate fuzzy blocking probability for all fuzzy arrival rate \(\lambda\) and blocking probability by using robust ranking technique as follows.

Table 3

<table>
<thead>
<tr>
<th>Fuzzy arrival rate ((\lambda))</th>
<th>Fuzzy Probability of Blocking When (\mu_1 = 35) (\mu_2 = 30)</th>
<th>Probability of Blocking When (\mu_1 = 35) (\mu_2 = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1,2,3,4)</td>
<td>((0.023, 0.052, 0.087, 0.131))</td>
<td>0.073</td>
</tr>
<tr>
<td>(6,7,8,9)</td>
<td>((0.135, 0.173, 0.217, 0.268))</td>
<td>0.198</td>
</tr>
<tr>
<td>(11,12,13,14)</td>
<td>((0.231, 0.274, 0.321, 0.377))</td>
<td>0.300</td>
</tr>
<tr>
<td>(16,17,18,19)</td>
<td>((0.277, 0.357, 0.407, 0.462))</td>
<td>0.375</td>
</tr>
<tr>
<td>(21,22,23,24)</td>
<td>((0.38, 0.427, 0.474, 0.662))</td>
<td>0.485</td>
</tr>
</tbody>
</table>
5.3. Suppose service rates at the two service points are not equal (i.e) \( \mu_2 = 30 , \mu_3 = 35 , \lambda = (1,2,3,4) \)

Assume \( \mu_2 = 30 , \mu_3 = 35 \)

FPB\( = [1 + \frac{1}{\mu_2} (1 + \frac{1}{\mu_3}) ] P (0,0) \)

Where \( P(0,0) = \frac{1}{1 + (1 + \frac{1}{\mu_1} + \frac{1}{\mu_2})} \)

Then we can calculate fuzzy blocking probability for all fuzzy arrival rate \( \lambda \) and blocking probability by using robust ranking technique as follows

<table>
<thead>
<tr>
<th>Fuzzy arrival rate ( \lambda )</th>
<th>Fuzzy Probability of Blocking When ( \mu_2 &lt; \mu_3 )</th>
<th>Probability of Blocking When ( \mu_2 &lt; \mu_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1,2,3,4)</td>
<td>(0.026,0.059,0.099,0.145)</td>
<td>0.082</td>
</tr>
<tr>
<td>(6,7,8,9)</td>
<td>(0.149,0.189,0.234,0.288)</td>
<td>0.215</td>
</tr>
<tr>
<td>(11,12,13,14)</td>
<td>(0.248,0.291,0.340,0.395)</td>
<td>0.318</td>
</tr>
<tr>
<td>(16,17,18,19)</td>
<td>(0.329,0.374,0.423,0.477)</td>
<td>0.400</td>
</tr>
<tr>
<td>(21,22,23,24)</td>
<td>(0.395,0.440,0.474,0.543)</td>
<td>0.463</td>
</tr>
</tbody>
</table>

6. Conclusion

In this paper we have established blocking probabilities for different fuzzy arrival rates. From the tables 2,3,4, we have concluded that generally blocking probability is reduced when service rates are increased. Even though service rates are increased, blocking probability is getting higher value when \( \mu_2 < \mu_3 \) comparing to other two cases. Among the remaining two cases when \( \mu_2 = \mu_3 = \mu \), blocking probability is reduced, provided service rates are increased at both service points. But at the same time when \( \mu_2 > \mu_3 \), i.e service rate is increased only at the first service point the blocking probability which is little higher than the case \( \mu_2 = \mu_3 = \mu \). Anyway this subtle difference does not affect the QoS improvement. Hence we choose the case \( \mu_2 > \mu_3 \) instead of choosing \( \mu_2 = \mu_3 = \mu \). The cost of the server also will be reduced when \( \mu_2 > \mu_3 \). Hence when service rate is increased in the MAC layer, QoS will be increased. using these phenomena, system designers can design the microcontroller and wireless transceiver chips effectively.

References

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