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The Analysis and Design of Handoff Process at MPLS-based Wireless Mobile Heterogeneous Networks Using Queueing Model with Capacity *c*

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Abstract:
The quality of service (QoS) will be not maintained when a communication link failed in a network. In order to assure reliable QoS requirements, a scheme to automatically reroute label switched paths is needed in MPLS network when communication links or routers failed. The time to recover a failed path is important to support the QoS guarantees by quickly rerouting connection. The objective of this paper focus on the analysis of recovery time when a failure path is detected. To analyze the recovery time, M/G/1 queueing model with capacity c is used. Using this model, we formulate the relationship among the failure rate of a routing path, the repaired rate to restore an alternative routing path or a protection path, and the number of availably alternative paths or protection paths to be planned.
Keywords: *MPLS, heterogeneous wireless network, handoff, hops*

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I. INTRODUCTION

To reduce the handoff latency, [1] proposed a hierarchical mobile MPLS [2-6] by introducing a foreign domain agent. Since a packet is traversed through several hops in the network to reach its destination, it encounters both delay and delay jitter depending on accumulating packets in the queue of hop and on the time to examine the destination address in hop's table lookup. These potential issues can be much reduced by an efficient label switching operation. To maintain the label bindings, label distribution protocol (LDP) is used and label distribution information is needed to be reliably transmitted between nodes in an MPLS network. In [2], FA forwards the registration message to the foreign domain agent instead of the HA of the mobile station. According to their simulation results, the end-to-end delay and handoff latency is still long for the delay sensitive applications. To improve these disadvantages, [7] proposed an adaptive hierarchical mobile MPLS scheme. In [7], this scheme is also based on the concept of foreign domain agent. Therefore, the handoff latency is not obviously enhanced. In [8], the author also adopts hierarchical of FAs to localize the registration traffic [9]. However, it does not support vertical handoff in [8].

In our system, horizontal handoff and vertical handoff are considered in different heterogeneous wireless technologies to resolve the handoff problem between two heterogeneous networks simultaneously. Time-slotted queueing model is considered here. Each slot can be assigned to a mobile station after handoff negotiation or acts as a slot by a contention-based reservation procedure. If a time slot is released due to the all scheduled packets' transmissions be completely transmitted, this slot is called as a departure slot. The slot which has some packets to contend or one handover packet is pre-assigned is called as arrival slot. Therefore, the discrete time queue models the size of data queue as the number of these slots which are reserved for the next packets' transmission. This differs from the assumption of pre-researches. If a time slot is reserved for a specific mobile station, only the new packet from the specific mobile station can be transmitted in this slot.

The basic requirement for mobile communication is that the active communicating connection should be accessible without any disruptions when the attached access point for a mobile station is changed. To achieve it, connection identifier can be associated and authenticated by the corresponding information is pre-exchanged between two base stations in our system. And the connection routing information is identified and authenticated by the related mesh nodes. In this work, we also assume that the time delay for a reservation traveling from a base station to the scheduled base station consists of time slots. The time length of each slot is not less than the round-trip time in our network. And all the IP addresses can be changed without affecting the connection identification.

When a communication link fails, it disrupts communication service for residential users. To guarantee the ability to provide some QoS, the system should be switched to the one of protection paths until the failed one is repaired. Therefore, the QoS in a high speed networking environment is concerned with the recovery time along the protection path. Recovery time is defined as the time interval from the instance that a failure in the network occurs to the instance that the failure condition is eliminated. To describe the efficiency of protection switching mechanism, the Markov chains of M/G/1 and M/M/1 with capacity *c* are used to derive the recovery time. In M/G/1 or M/M/1 models, capacity *c* represents the number of recovery paths which can be switched to reroute the traffic such that network resource is efficiently used at a fixed mean repaired time. Repaired time is defined as the time interval from the instance that failure links in the network begin to be repaired to the instance that these links can successfully forward packets to the corresponding destinations. The arrival rate is viewed as the failure rate of a communication link. As the transmitting end detects the failure, the actually repair processing begins at the beginning of recovery operation time. Therefore, the service rate is viewed as the repaired rate. To enforce strict recovery time guarantees, fault detection time is a key component of the total recovery time which depends on the fault detection mechanism in use. Therefore, the waiting time is viewed as the sum of hold-off time and fault notification time [3]. The delay time is viewed as the recovery time. In other words, the recovery time equals the sum of fault detection time, waiting time and repaired time (the sum of recovery operation time and traffic recovery time).

MPLS can establish some bind of connection by distributing labels across the network. The significance of label is only on a local node-to-node connection. Combining with differentiated services, faster switching operation and traffic engineering, guaranteed QoS can be implemented into the connections using pre-established and reversed label switch paths. In MPLS networks, link congestion may be arisen and incoming traffic will be rejected. Therefore, the knowledge of the edge LSR should be exploited to reduce the number of request rejections due to the insufficiency of network capacity. Since we assume that the buffer to record the messages of these failure links, traffic loss and blocking delay is not necessary to be discussed. In this paper, we also assume that traffic throughput and resource utilization are maximized during the recovery time as possible to deliver a reliable service.

The rest of this paper is organized as follows; in Section 2, we describe the system operation of FTA hierarchy structure based on the concept of the MPLS network. In Section 3, the mean waiting time from our established M/G/1 with capacity *c* queuing is derived. Section 4 presents the numerical results of M/M/1 queueing with capacity c and the concluding remarks are discussed in Section 5.

II. HIERARCHICAL MOBILE MPLS SYSTEM

The one objective of a cross-layer design is to enhance the mobility management when MH changes its mobility agent and register. To obtain better performance, FTA is proposed here and is responsible for layer 2 mobility of MH. But it executes layer 3 protocol if it wants to take over the routing and handoff. All corresponding label message are also exchanged among neighbor's FTA by the authentication and verification processes. Notice that the release requires and release replies are exchanged only between the FTA and the previous FA. And the transmitted packets are forwarded crossings relative FTA through the new FA. Under mobile MPLS network, FA just knows the labels from its adjacent FAs. But FTA must obtain all labels from FAs which are in its coverage.

In our scheme, FTA is able to send packets directly to the new FA without the services of immediate FAs, see Figure 1, and does not support the function to page the MH. This operation gives a smooth handoff mechanism when a MH moves away from one foreign network to another and is described as follows.

Step 1 - The pre-reservation channel is negotiated between FTA and a FA before handoff using tracking scheme.
Step 2 - When a MH moves to the new FA which it visited, it must get the care-of address of the new visited FA.
Step 3 - When the MH wants to register with the new visited FA, it has to send a registration require.
Step 4 - After receiving the registration request, the new visited FA sends an update request to the FTA.
Step 5 - FTA returns an update reply to the new which is visited by the MH after it received the update request.
Step 6 - The new visited FA sends a registration reply to the MH with a label and a pre-reservation channel.
Step 7 - FTA sends a release request to the previous FA.
Step 8 - After receiving the release request, the previous FA returns a release reply to the FTA. Then, the handoff procedure is completed.

This scheme will not cause longer handoff latency and channel contention time. It also provides multiple real-time services while also achieving high quality of service support. In our system, we assume that there are enough resources to satisfy the QoS requirement of MH during handoff procedure.

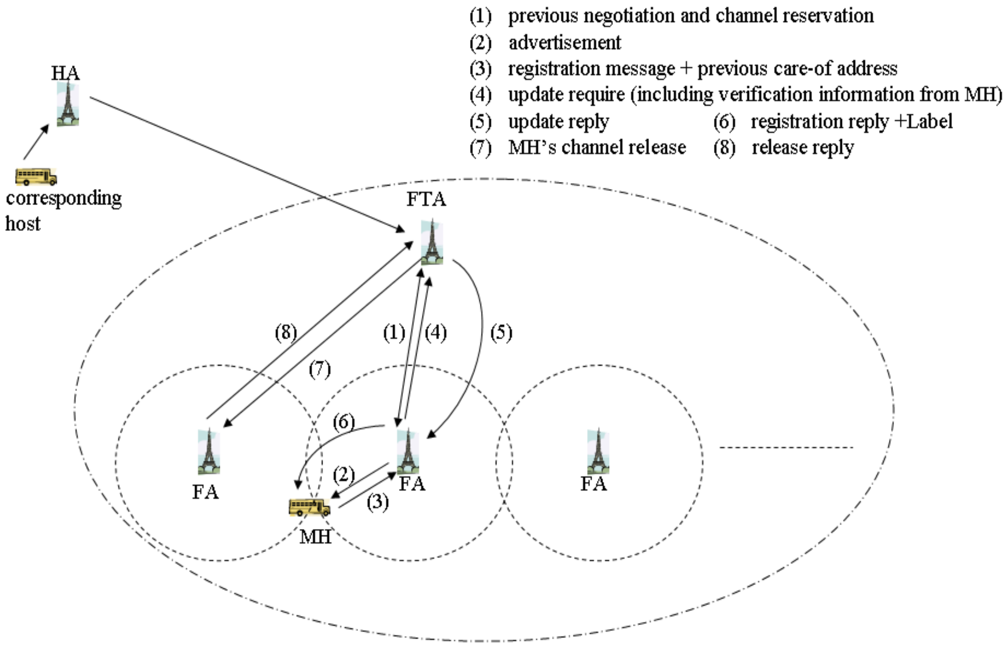

Figure 1. The FTA system

III. WAITING TIME IN M/G/1QUEUEING WITH CAPACITY *C*

The Poisson process is an extremely useful process for modeling purposes in many practical applications, such as to model arrival processes for queueing models or demand processes for inventory systems. It is empirically found that in many circumstances the arising stochastic processes can be well approximated by a Poisson process. To observe the queueing length for a given arrival after a partial period U of a service time, we find that the observed queueing length rely on U and the residual service time and is no longer stochastically the same as that of the steady state. Therefore, M/G/1 queue is used to argue that the queue left behind after a departure comprises precisely those packets that arrived during the departing packet's sojourn [10]. In addition, the model of the M/G/1 queueing has proved to be very useful in the performance evaluation of many types of telecommunication systems [11].

To describe the efficiency of protection switching mechanism, the Markov chains of M/G/1 and M/M/1 with capacity c are used to derive the mean delay time. In this section, we assume that the service rate is constant regardless of re-optimization be either triggered or not. Various service rates can be corresponding to different packet processing or handoff and tracking recovery mechanisms. When the service rate is related to a handoff mechanism, the arrival rate can be viewed as the rate that a handoff is occurred. Before obtaining the mean delay time, we want to discuss the performance characteristics of M/G/1 model with capacity c for a queue. Based on M/G/1 model, denoted $X_n = X(t_n)$ to be the number of arrivals remaining in the system as the nth traffic departs at the completion time t_n, and $A_n = A(t_n)$ to be the number of traffics who arrived during the service time of the nth traffic. Under work-conserving policy, the queue is governed by the following recursive equation [12].

$$X_{n+1} = (X_n - c)^+ + A_{n+1} \tag{1}$$

Denote

$$\begin{aligned} U_n &\equiv 1_{\{X_n \ge c\}} \equiv \begin{cases} 1, \, if \;\; X_n \ge c \\ 0, \, if \;\; X_n < c \end{cases} \\ U_n^c &\equiv 1_{\{0 < X_n < c\}} \\ I_n &\equiv 1_{\{X_n \ge 1\}} \end{aligned} \tag{2}$$

and $(x)^+ = \max\{0, x\}$. Then

$$\begin{aligned} X_{n+1} &= (X_n - c)U_n + A_{n+1} \\ &= (X_n - c)(I_n - U_n^c) + A_{n+1} \\ &= X_n - cI_n + A_{n+1} - (X_n - c)U_n^c \end{aligned} \tag{3}$$

Random variable of service time $\widetilde{S}$ is assumed to be independent of previous service time and the length of the queue (or queueing length). We also assume that the service times are independent and identically distributed random variables with an arbitrary cumulative probability distribution.

Since we have assumed that the arrivals are Poisson input, the random variable of arrivals A only depends on $\widetilde{S}$ and not on the queue or on the time of service initiation. For simplicity of analysis, we assume that no new tags are allowed any collision resolution cycle if the RFID reader has detected some collision packet periods at the previous collision resolution cycle. That is, assume that the operation of the RFID protocol is gated exhaustive. Herein, we define a collision packet period as the time interval in which the RFID reader serves these packets with a specifically transmitted slot. Similarly, we define a non-collision packet as the time interval in which the RFID reader servers the tag that only exists in a specially transmitted slot.

3.1. The derivation of queueing length

Based on the assumption that our system is a stationary system, the expectation of queueing length (denoted as L_D) and the variance of queueing length at departure points have the following characteristics.

$$\begin{aligned} E[X_{n+1}] &= E[X_n] = L_D \\ Var[X_{n+1}] &= Var[X_n] \end{aligned} \tag{4}$$

From Appendix A, the mean queueing length is obtained as

$$\begin{aligned} L_D &= \frac{cE[A] + E[A^2] - 2E^2[A] - \left(cE\left[(X_n - c)U_n^c\right] + E[(X_n - c)^2 U_n^c]\right)}{2(c - E[A])} \\ &= \frac{c\lambda E[\widetilde{S}] + E[A^2] - 2\lambda^2 E^2[\widetilde{S}] - \left(cE\left[(X_n - c)U_n^c\right] + E[(X_n - c)^2 U_n^c]\right)}{2\left(c - \lambda E[\widetilde{S}]\right)} \end{aligned} \tag{5}$$

Denoted σ_s^2 to be the variance of service time distribution, the variance of random variable A is [5]

$$\begin{aligned} Var[A] &= E[Var[A \mid \widetilde{S}]] + Var[E[A \mid \widetilde{S}]] \\ &= E\left[\lambda\widetilde{S}\right] + Var\left[\lambda\widetilde{S}\right] \\ &= \lambda E[\widetilde{S}] + \lambda^2 Var\left[\widetilde{S}\right] \\ &= \lambda E[\widetilde{S}] + \lambda^2 \sigma_S^2 \end{aligned} \tag{6}$$

Let $\rho \equiv \lambda E[\widetilde{S}]$ represent the system utilization. Due to

$$\begin{aligned} E[A^2] &= Var[A] + E^2[A] \\ &= Var[A] + \lambda^2 E^2\left[\widetilde{S}\right] \end{aligned} \tag{7}$$

we have

$$\begin{aligned} & c\lambda E[\widetilde{S}] + E[A^2] - 2\lambda^2 E^2[\widetilde{S}] - \left(cE\left[(X_n - c)U_n^c\right] + E[(X_n - c)^2 U_n^c]\right) \\ &= c\lambda E[\widetilde{S}] + \left(\lambda E[\widetilde{S}] + \lambda^2\sigma_S^2 + \lambda^2 E^2[\widetilde{S}]\right) - 2\lambda^2 E^2[\widetilde{S}] - \left(cE\left[(X_n - c)U_n^c\right] + E[(X_n - c)^2 U_n^c]\right) \\ &= \lambda(c+1)E[\widetilde{S}] + \lambda^2\sigma_S^2 - \lambda^2 E^2\left[\widetilde{S}\right] - \left(cE\left[(X_n - c)U_n^c\right] + E\left[(X_n - c)^2 U_n^c\right]\right) \end{aligned} \tag{8}$$

Since

$$\begin{aligned} cE\left[(X_n - c)U_n^c\right] + E\left[(X_n - c)^2 U_n^c\right] &= cE\left[\left(X_n U_n^c\right) - \left(cU_n^c\right)\right] + E\left[\left(X_n^2 - 2X_n c + c^2\right)U_n^c\right] \\ &= cE\left[\left(X_n U_n^c\right) - cE\left(cU_n^c\right)\right] + E\left[\left(X_n^2 U_n^c\right) - 2cE\left[X_n U_n^c\right] + c^2 E\left[U_n^c\right]\right] \\ &= E\left[X_n^2 U_n^c\right] - cE\left[X_n U_n^c\right] \end{aligned} \tag{9}$$

the expectation of the random variable number of traffics in the system at steady state is

$$L_D = \frac{\lambda(c+1)E[\widetilde{S}] + \lambda^2\sigma_S^2 - \lambda^2 E^2\left[\widetilde{S}\right] - \left(E\left[X_n^2 U_n^c\right] - cE\left[X_n U_n^c\right]\right)}{2(c - \lambda E[\widetilde{S}])} \tag{10}$$

3.2. **Mean delay time**

Denote the random variable $E[\widetilde{W}]$ be the waiting time beginning to repair the failure path(s) immediately upon arrival. From Little's theory, the mean waiting time for the queue is given as

$$E\left[\widetilde{W}\right] = \frac{L_D}{\lambda} = \frac{(c+1)E[\widetilde{S}] + \lambda\sigma_S^2 - \lambda E^2[\widetilde{S}] - \dfrac{\left(E\left[X_n^2 U_n^c\right] - cE\left[X_n U_n^c\right]\right)}{\lambda}}{2(c - \lambda E[\widetilde{S}])} \tag{11}$$

Corresponding to the problem of network recovery, the mean recovery time as the statement in Section 1 is given as

$$E[\widetilde{D}] = E[\widetilde{W}] + E[\widetilde{S}] + E[\widetilde{R}] \tag{12}$$

where $E[\widetilde{R}]$ is the mean fault detection time. If the value of $E[\widetilde{R}]$ can be given, the mean recovery time can be precisely obtained.

3.3. M/M/1 queueing with capacity c

For the system model of M/M/1 queueing, the state-transition-rate diagram can be viewed as a state-transition-rate diagram for the number of customers in the bulk service system. According to the analyzed results in [13], we have

$$\pi_n = (1-\gamma_0)\gamma_0^n \tag{13}$$

Where $\gamma_0<1$ is the solution of the following equation: $\rho\gamma_0^c - \gamma_0^{c-1} - \gamma_0^{c-2} - \cdots\cdots - 1 = 0$. After some mathematical operations, we obtain

$$E\left[X_n^2 U_n^c\right] = \sum_{i=1}^{c-1} i^2 (1-\gamma_0)\gamma_0^i = \frac{\gamma_0(1+\gamma_0)}{(1-\gamma_0)^2} - \frac{(1+\gamma_0)\gamma_0^{c+1}}{(1-\gamma_0)^2} - \gamma_0^c c^2 - \frac{2\gamma_0}{1-\gamma_0} c\gamma_0^c \tag{14}$$

$$E\left[X_n U_n^x\right] = \sum_{i=1}^{x-1} i(1-\gamma_0)\gamma_0^i = \frac{\gamma_0\left\{1 - x\gamma_0^{x-1}(1-\gamma_0) - \gamma_0^x\right\}}{1-\gamma_0} = \frac{\gamma_0}{1-\gamma_0} - x\gamma_0^x - \frac{\gamma_0^{x+1}}{1-\gamma_0} \tag{15}$$

Let us force the variance of service time to be maintained at a fixed level. To maintain the system utilization and obtain the minimum mean waiting time, we can obtain the relationship between maximum failure rate and system utilization by setting $dE[\widetilde{W}]/d\lambda = 0$ at the low traffic condition. Under this assumption, we obtain $\gamma_0 \cong \rho$. After some mathematical operations, we obtain

$$\lambda^3\sigma_s^2\rho + \left[(c-\rho)\sigma_s^2 - \frac{(c-\rho)\beta}{\mu(1-\rho)^4 - \rho\alpha}\right]\lambda^2 = -\rho^2(c+1-\rho) + \rho^2(c-\rho) \tag{16}$$

where

$$\alpha = \frac{\rho\left((1+\rho)(1-\rho^c) - c(1-\rho)(1+\rho^c)\right)}{(1-\rho)^2}$$

$$\beta = c(c-1)\rho^{c+3} - (3c^2-4)\rho^{c+2} + (3c^2+3c-2)\rho^{c+1} - (c+3)\rho^2 - (c^2-1)\rho - c + 1 \tag{17}$$

IV. NUMERICAL RESULT

In this section, we will illustrate the relationship between queueing parameters (such as repaired rate, failure rate) based on the mathematical analyses. To clarify the effect of these parameters as much as possible for each comparison, according to our following results, we will alter only one parameter and maintain the others unchanged. Based on the M/M/1 queueing model, $\sigma_s=\mu^{-1}$. The first comparison is made by varying the mean repaired time in the environments to compare with different value of c.

From Fig-2 to Fig-4, we show that the mean waiting time increases with increment of mean repaired time under one MPLS router. This phenomenon incurs due to the time to avoid any racing condition at performing an alternate path and the fault notification time to the originating LSR. However, if the number of protection paths is greater than one (c>1), the curves are approximate a straight line between mean waiting time and the mean repaired time. In additional, Figures also reveal that the more the number of protection paths are, the less the waiting time is.

The second comparison is made by varying the value of mean repaired time in the environments to compare with different value of mean failure rate, λ by setting c=5 and c=10, respectively. Fig-5 and Fig-6 reveal that the mean waiting time increases with increment of λ. Fig-5 and Fig-6 also reveal that the faster the mean repaired time is, the less the waiting time is.

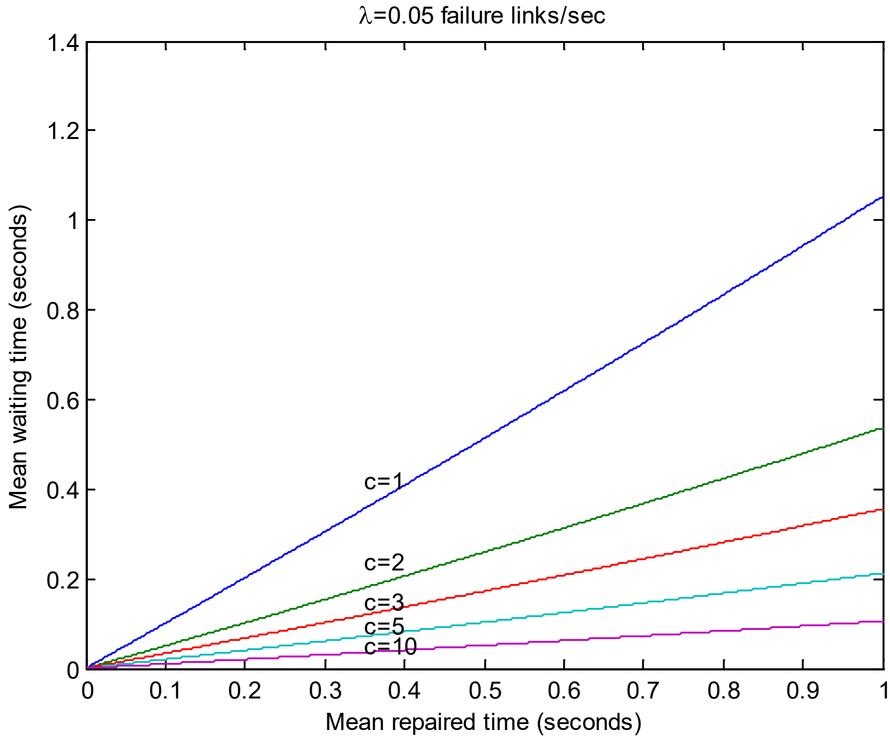

Figure 2. The relationship between mean waiting time and mean repaired time for various *c* at $\lambda = 0.05$.

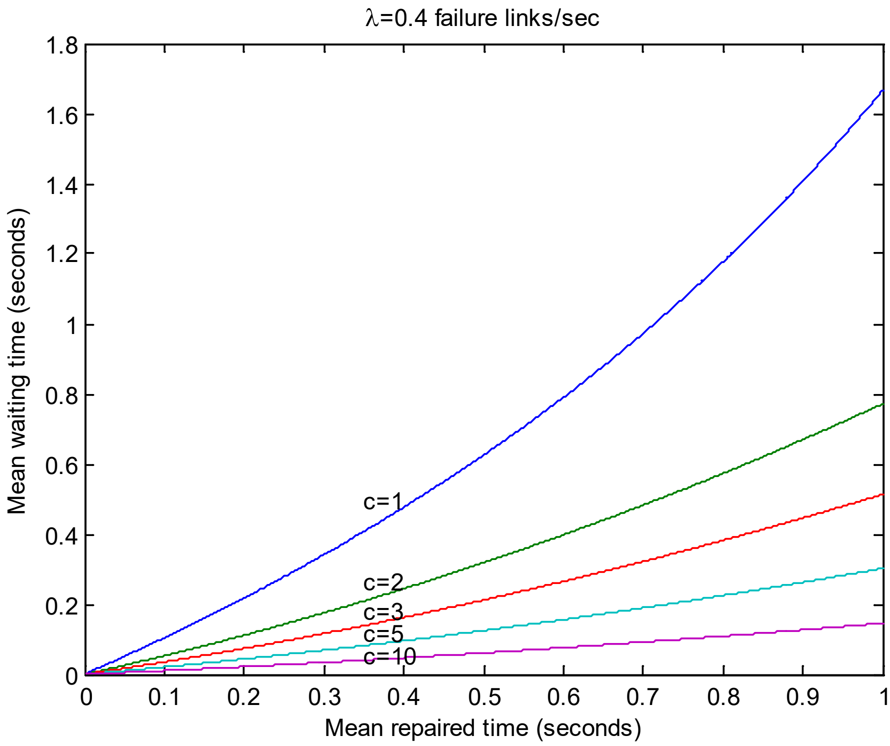

Figure 3. The relationship between mean waiting time and mean repaired time for various *c* at $\lambda = 0.4$

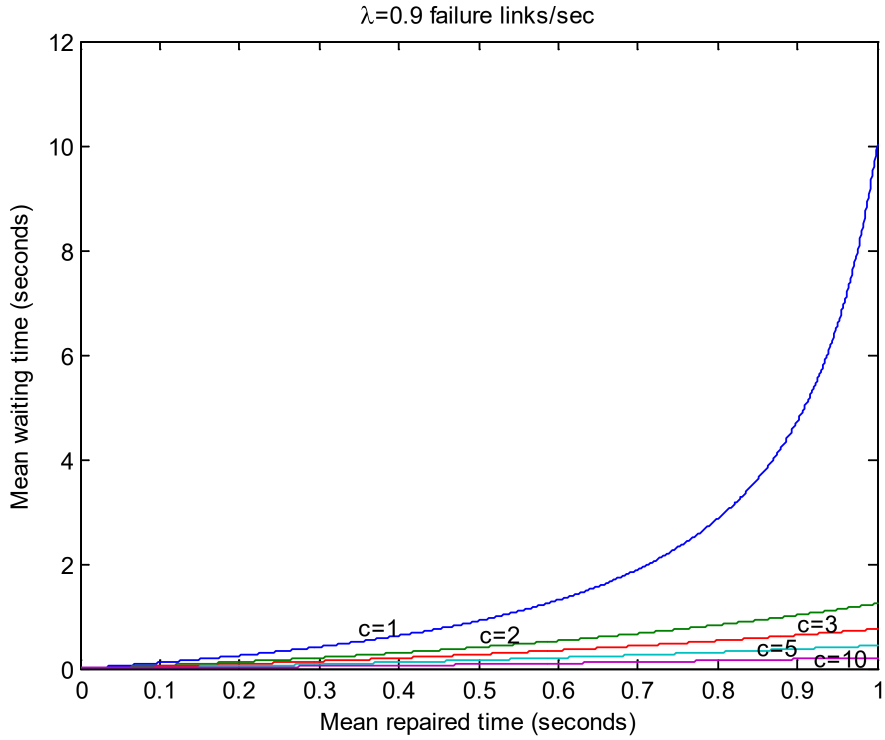

Figure 4. The relationship between mean waiting time and mean repaired time for various c at $\lambda = 0.9$

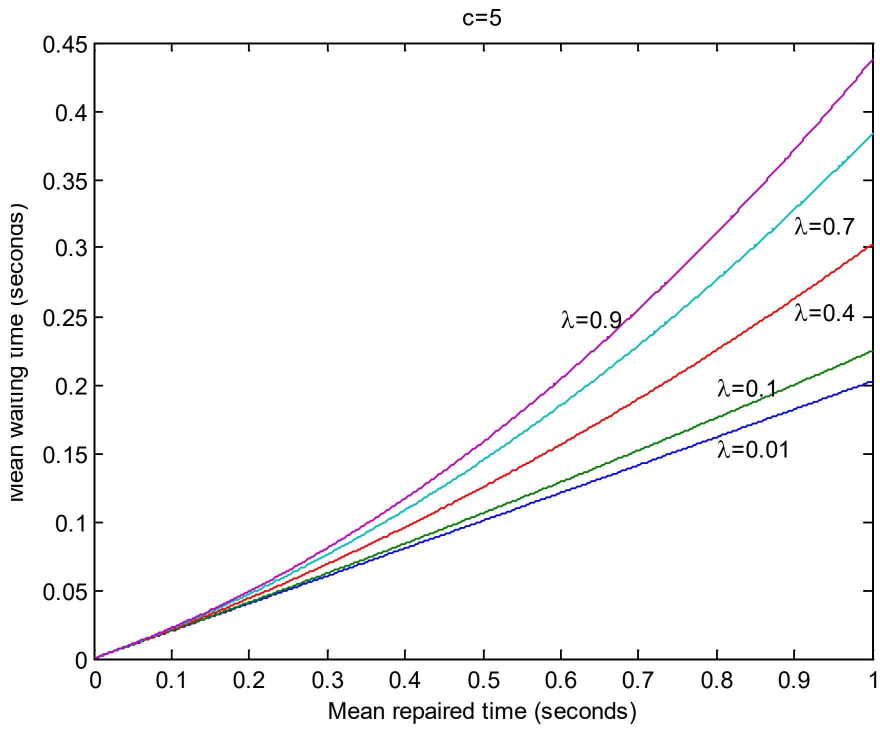

Figure 5. The relationship between mean waiting time and mean repaired time for various λ at c=5.

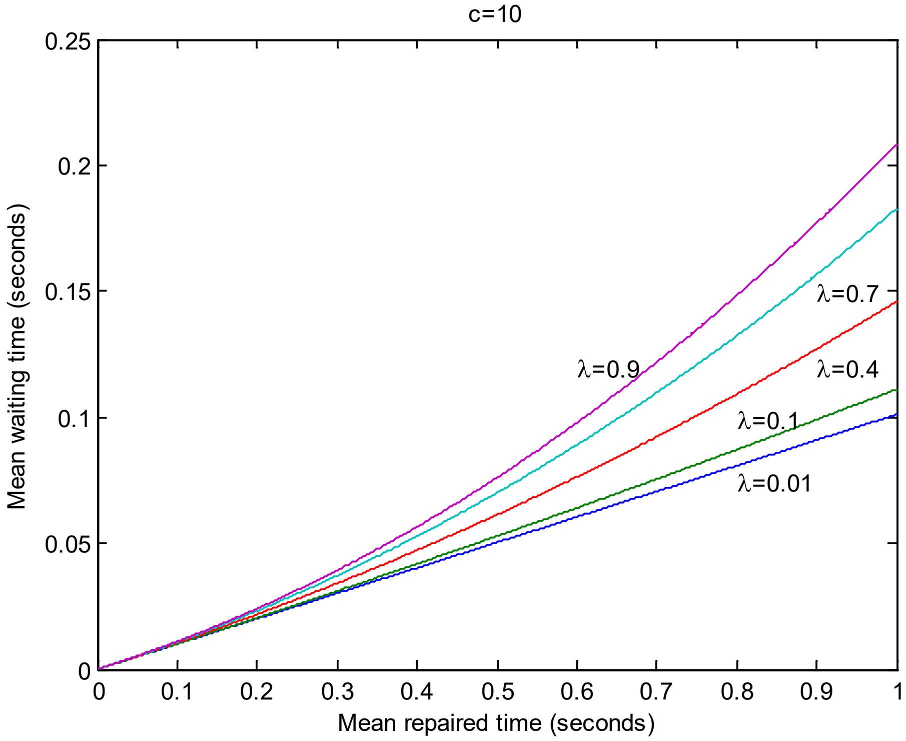

Figure 6. The relationship between mean waiting time and mean repaired time for various λ at c=10.

Let us force the variance of service time to be maintained at a fixed level, saying $\sigma_s=1$. A sketch of the failure rate versus the system utilization for various c is shown in Fig-7. As is expected, the lower c the larger the failure rate. Note however, for smaller value of failure rate λ, there are two values of ρ to which it corresponds - one larger and one smaller than the value of ρ corresponding to the maximum failure rate. The smaller one is conditionally stable while the other one is conditionally unstable. It means that if the failure rate increases beyond that point with maximum value, the failure rate that one LSR in a MPLS network can be approved approaches to be zero if the network drifts to higher ρ.

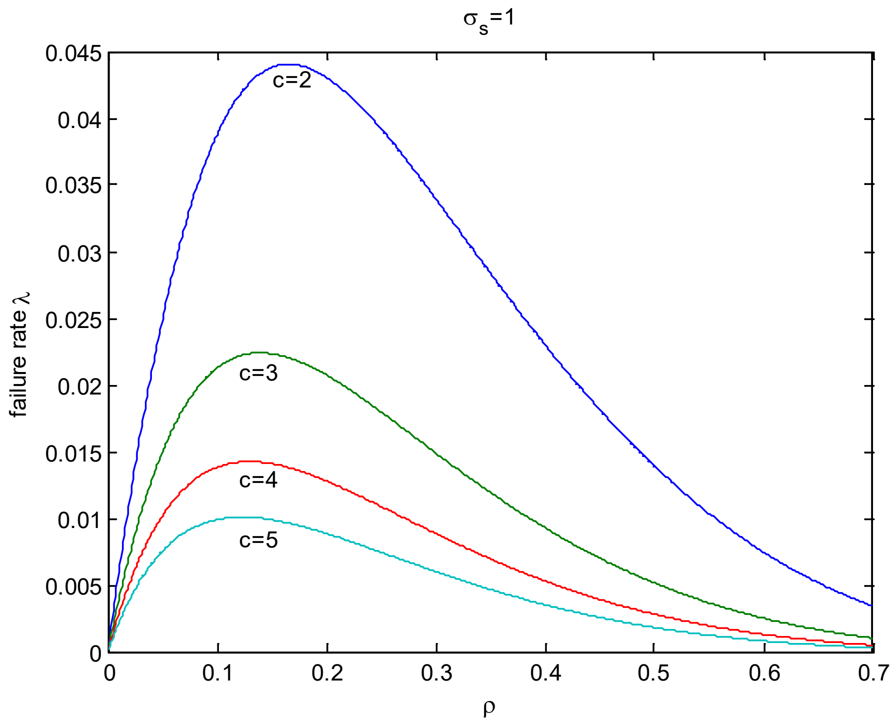

Figure 7. The relationship between maximum failure rate and ρ to obtain the minimum mean waiting time for various c.

V. CONCLUSIONS

In this paper, we use M/G/1 and/or M/M/1 with capacity *c* queueing model to analyze the waiting time (or recovery time). We also give the suggested number of protection paths reflecting its estimated mean recovery time to provide the possible QoS according to the failure rate of communication link in MPLS network. Although fault detection time depends on the recovery mechanism, it is not mentioned here. The performance related to the variety of failure rate for the finite number of LSRs will be studied in the future work.

Appendix A. The derivation of mean queueing length

$$E[X_{n+1}] = E[X_n] - cE[I_n] + E[A_{n+1}] - E[(X_n - c)U_n^c] \tag{18}$$

or

$$L_D = L_D - cE[I_n] + E[A_{n+1}] - E[(X_n - c)U_n^c] \tag{19}$$

or

$$\begin{aligned} cE[I_n] &= E[A_{n+1}] - E[(X_n - c)U_n^c] \\ &= E[A] - E[(X_n - c)U_n^c] \\ &= \lambda E[\widetilde{S}] - E[(X_n - c)U_n^c] \end{aligned} \tag{20}$$

Squaring (3), we have

$$\begin{aligned} X_{n+1}^2 &= [X_n - cI_n + A_{n+1} - (X_n - c)U_n^c]^2 \\ &= [X_n - cI_n + A_{n+1}]^2 + [(X_n - c)U_n^c]^2 - \\ &\quad 2[X_n - cI_n + A_{n+1}][(X_n - c)U_n^c] \\ &= X_n^2 + c^2 I_n^2 + A_{n+1}^2 - 2cX_n I_n - 2cA_{n+1}I_n + 2A_{n+1}X_n + \\ &\quad (X_n - c)^2 (U_n^c)^2 - 2[X_n - cI_n + A_{n+1}][(X_n - c)U_n^c] \end{aligned} \tag{21}$$

Since

$$\begin{aligned} [X_n - cI_n][(X_n - c)U_n^c] &= [(X_n - c)I_n][(X_n - c)U_n^c] \\ &= (X_n - c)^2 I_n U_n^c \\ &= (X_n - c)^2 U_n^c \end{aligned} \tag{22}$$

we have

$$\begin{aligned} E[X_{n+1}^2] &= E[X_n^2] + c^2 E[I_n^2] + E[A_{n+1}^2] - 2cE[X_n I_n] - 2cE[A_{n+1}I_n] + 2E[A_{n+1}X_n] + E[(X_n - c)^2 (U_n^c)^2] - \\ &\quad 2E[(X_n - cI_n + A_{n+1})[(X_n - c)U_n^c]] \\ &= E[X_n^2] + c^2 E[I_n^2] + E[A_{n+1}^2] - 2cE[X_n I_n] - 2cE[A_{n+1}I_n] + 2E[A_{n+1}X_n] + E[(X_n - c)^2 (U_n^c)^2] - \\ &\quad 2\{E[A_{n+1}]E[(X_n - c)U_n^c]\} - 2E[(X_n - c)^2 U_n^c] \end{aligned} \tag{23}$$

Since

$$\begin{aligned} E[I_n^2] &= E[I_n] \\ E[X_n I_n] &= E[X_n] \\ (U_n^c)^2 &= U_n^c \end{aligned} \tag{24}$$

we have

$$\begin{aligned} 0 &= c(cE[I_n]) + E[A_{n+1}^2] - 2cE[X_n] - 2E[A_{n+1}](cE[I_n]) + 2E[A_{n+1}]E[X_n] - E[(X_n - c)^2 U_n^c] - 2E[A_{n+1}]E[(X_n - c)U_n^c] \\ &= c(E[A] - E[(X_n - c)U_n^c]) + E[A^2] - 2cL_D - 2E[A](E[A] - E[(X_n - c)U_n^c]) + 2E[A]L_D - E[(X_n - c)^2 U_n^c] - \\ &\quad 2E[A]E[(X_n - c)U_n^c] \\ &= cE[A] - c(E[(X_n - c)U_n^c]) + E[A^2] - 2cL_D - 2(E[A])^2 + 2E[A]E[(X_n - c)U_n^c] + \quad 2E[A]L_D - E[(X_n - c)^2 U_n^c] - \\ &\quad 2E[A]E[(X_n - c)U_n^c] \\ &= L_D(2E[A] - 2c) + E[A^2] - 2E^2[A] + cE[A] - cE[(X_n - c)U_n^c] - E[(X_n - c)^2 U_n^c] \end{aligned} \tag{25}$$

or

$$L_D = \frac{cE[A] + E[A^2] - 2E^2[A] - \left(cE\left[(X_n - c)U_n^c\right] + E[(X_n - c)^2 U_n^c]\right)}{2\left(c - E[A]\right)}$$
$$= \frac{c\lambda E[\widetilde{S}] + E[A^2] - 2\lambda^2 E^2[\widetilde{S}] - \left(cE\left[(X_n - c)U_n^c\right] + E[(X_n - c)^2 U_n^c]\right)}{2\left(c - \lambda E[\widetilde{S}]\right)} \quad (26)$$

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