Performance Modeling and Analysis of Distributed-Based Polling Networks

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Abstract

In this paper, the performance evaluation of distributed polling networks using the analytical equations and a developed simulation model is considered. The exhaustive service versus K-limited service are also investigated and compared. Other main measurements such as average cycle time, walking time are also compared and calculated. In general, the result of both our designed simulation and analytical equations are almost in total agreements. Our simulation model and performance evaluations can be used as a basis to investigated or develop many polling-based wireless protocols. The differences between the analytical and simulation values came from the approximation done on the analytical equations.

Keywords: Distribution polling, performance analysis, queuing system, system modulation.

1. Introduction

Polling is a general way of multiplexing service requests for a single server from multiple stations. The basic concept of polling network system is to have multiple queues accessed by a single server in cyclic order [1-5]. polling systems whose study dates from the late 1950's found wide applications, for example in telecommunications, transportation, healthcare, etc., and have been the subject of numerous studies [6-14]. This is because it provides general performance analysis criteria for a large number of demand-based and multiple access schemes in computer and communication schemes. Nowadays, polling has been included as a resource sharing mechanism in the Medium Access Control (MAC) protocol for several wireless networks, such as wireless networks [6,7], IEEE 802.16 broadband wireless networks [8], IEEE 802.11 wireless LANs [9-11], and broadband wireless networks [12]. In addition, it have been used in network such as Ethernet passive optical network [13].The concept behind this is because, polling-based one performs better in heavy loads, Compared with another contention-based MAC protocol [14].

In this paper, we develop a simulation model in order to investigate the performance of distributed poling networks with exhaustive and K-limited services at certain conditions and compared that with the derived analytical equations. We aimed from this to make a basis for extending this protocol in more MAC wireless protocols. Their simulation results are simulated and compared with its analytical equations.

The rest of this paper is organized as follows. In section 2, the distributed poling network model is presented. In section 3, the simulation model is explained. In Section 4, the comparisons between the simulation and analytical results are compared. Finally, conclusions are provided in sections 5.

2. Polling Network Modeling

A polling network is a computer communications network that uses *polling* to control access to the network. Each node or station on the network is given exclusive access to the network in a predetermined order. Permission to transmit on the network is passed from station to station using a special message called a *poll*. Polling may be centralized (often called *hub polling*) or decentralized (*distributed*). In hub polling, the polling order is maintained by a single central station or *hub*. When a station finishes its turn transmitting, it sends a message to the hub, which then forwards the poll to the next station in the polling sequence. In a decentralized polling scheme, each station knows its successor in the polling sequence and sends the poll directly to that station. To simplify matters, we will assume a distributed polling scheme.

We divide time into alternating types of intervals: *polling intervals*, during which the poll is transferred between stations, and *transmission intervals*, during which the station with the poll transmits packets [1-5].

Polling networks come in three flavors: gated, exhaustive, and partially gated as follows [3]:

- *Exhaustive Policy*: If an exhaustive policy is in use, the server serves all packets at a queue that it finds upon arrival there, and the new packets that arrive after the server (while serving).
- *Gated Policy*: If a gated policy is in use, the server serves all packets at a queue that it finds upon arrival there, but no new packets that arrive after the server will be served.

- *Limited Policy*: If a limited policy is in use, the server serves a limited number of packets.

The polling network model for this simulation uses distributed polling. There are N queues indexed by *i*, 0 <= *i* <= N - 1. There is a single server that moves successively from queue i to queue (*i* + 1) mod N as shown in Fig. 1. The rate at witch packets arrive at a station for transmission on the network is the same for all stations. To simplify the model, we assume all packets except the poll are of the same length (constant packet lengths). A station that has permission to transmit (received the poll) transmits exhaustively, that is, until all massages in its input queue have been transmitted. This includes any packets that might arrive while the station has the poll and is transmitting other packets on the network. Packets arrive at each station according to a Poisson or Bernoulli process, independent of all other arrivals. The arrival rates at the station are identical.

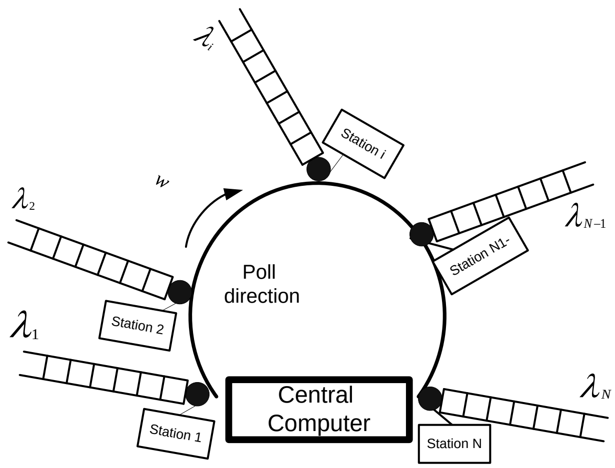

Fig. 1 Polling Network Model

The server has a switchover time to go from queue *i* to queue (*i* + 1) mod N with fixed delay. This is called walk time (*w*) and it is required to transfer the poll from one station to another and synchronize the station for transmission to the central computer. We assume that the distance between stations are equals, so that the walks time are equals. The total time required to poll each station and return to the starting station in the polling sequence is called cycle time and the average cycle time is T_C as shown in Fig. 2.

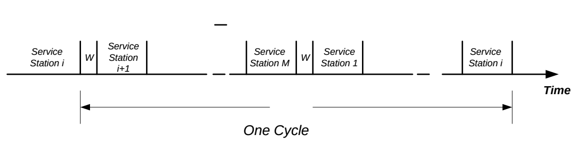

Fig. 2 Cycle Time of one Poll (M<=N)

The server model for polling system with exhaustive service is shown in Fig. 3.

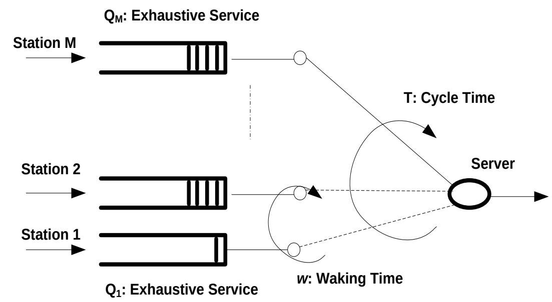

Fig. 3 Server Model for Polling Network

Each packet at queue *i* requires a service time that is related to the packet length, but since the packets size are equally likely then the service time is assumed to be constant time. The packets service times, walk time (*w*) and packets arrival processes are all mutually independent.

3. Simulation Process Model

As mentioned in section 2, the polling scheme with exhaustive service may be described with the following rules.

- The server polls the stations by sending a POLL packet.
- If the buffer queue of the polled station is not empty, then the station responds to each POLL packet by sending the data packets from its buffer queue exhaustively, that is, until all massages in its input queue have been transmitted. This includes any packets that might arrive while the station has the POLL and is transmitting other packets on the network
- If the buffer queue of the polled station is empty, then the station responds to each POLL packet by sending an empty (NULL) packet.
- The exchange ends after the queue buffer is empty.
- After the end of exchange, the server moves on to Poll next station.
- When all the stations have been visited, the sequence is cyclically repeated.

In case of K-limited service, the server will serve K packets at maximum at each visit. In this case the above rules will have the following modification:

- The exchange ends after K packets services finish or the queue buffer is empty whichever comes first.
- After exactly K packets services finish, the exchange ends regardless of the state of station's queue even there are new arrival packets during the period of the this services.

In this research we use C++ platform to simulate the studied system. As shown in Fig. 4 , we have three main types of events:

- *Packet Arrival event:* Packets arrive at queue *i* according to a Poisson process with the rate λ_i. where the inter-arrival time is exponentially distributed, and the Next Arrival Time (Packets) = Clock Time + (- 1/ λ_i ln(u)) Where 0 <= u <=1
- *Poll Arrival Event:* Next Arrival Time (Poll) = Clock Time + WalkTime(*w*) where *w* is small constant value of time. The sequence of Next station= (current station sequence +1) mod N
- *Completion Event:* Time of service Completion= Clock Time + Service Time (*s*) where s is constant value of time.

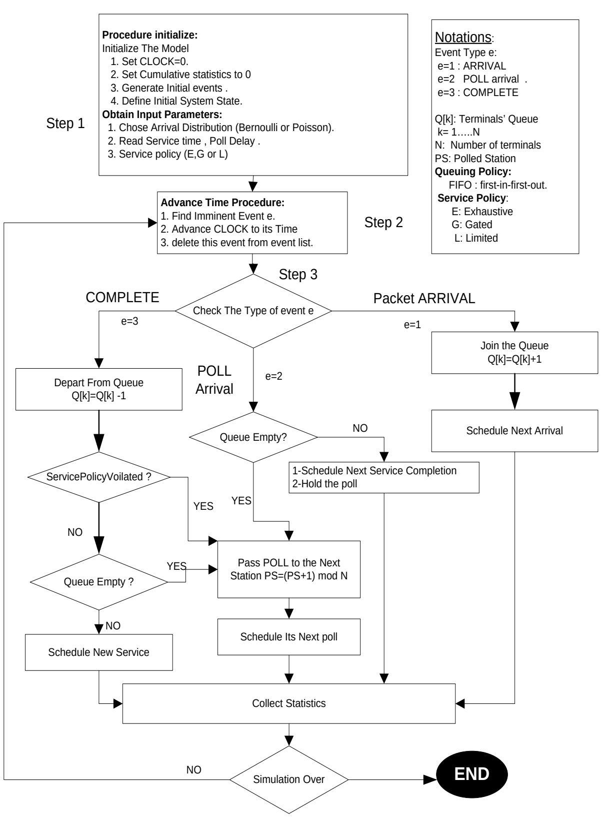

Fig. 4 : Simulation Model Flowchart

4. Performance Analysis

In this section, we present our performance study for the distributed exhaustive and K-limited poling network. The delay, throughput and performance of the K-limited services polling networks are compared with that of analytical equations under different network conditions.

4.1 Performance measurements and assumptions

In determining the performance, the following assumptions are made:

- Each station has the same Poisson arrival statistics with average arrival rate λ_i packets/second.
- The walk time (w) between stations is constant and the same for every consecutive station.
- The channel propagation times between stations are equal and are included in the walk time (w).
- Packet length distributions are the same for packets arriving at each station.

The analytical performance measures are derived in details in [2-5]. In this paper, the following selected parameters will be used to measure the performance:

- *Throughput* (S): the ratio of the total average arrival rate to the network to the total capacity of the network (both in packets/second).

$$S = \frac{M\lambda \overline{X}}{R} \qquad (1)$$

Where X is the first moment of packet length and R is the channel capacity

- *Average cycle time* (T_c): the total time required to poll each station and return to the starting station in the polling sequence

$$T_c = \frac{Mw}{1-S} \qquad (2)$$

- *Average waiting delay* (W): it is divided into to components
  - the waiting delay in the station buffer while other station are being served.
  - the waiting delay in the station buffer while the particular station is being served.

$$W = \frac{Mw(1-S/M)}{2(1-S)} + \frac{S\,\overline{X}}{2R(1-S)} \qquad (3)$$

Assuming constant packet lengths

- *Average number of packets stored in a station buffer* (N) : it is divided into two parts
  - Those packets that arrive while a station inactive
  - Those packets that arrive while the station is being served.

$$N = \lambda W = \frac{Mw\lambda(1-S/M)}{2(1-S)} + \frac{S\lambda \overline{X}}{2R(1-S)} \qquad (4)$$

- *Average transfer delay (T)*: the total average time between packet arrival at station and its delivery to the central computer.

$$T = \frac{\overline{X}}{R} + \tau + W \qquad (5)$$

where τ is the end-to-end prorogation delay for the bus.

In the simulation, we assume that: (1) one server and M stations; (2) the length of time slot is 10 ms; (3) the Switchover time when the server poll the stations from the (i)th to the (i+1)th is one slot; (4) the arriving process of the packets is according to Poisson arrival process. (Arrival rate =0.4 packets/sec , Tc=0.2 sec, w=0.05 msec)

4.2 Comparing analytical and simulation results

In this section we compare the results of our simulation model with the analytical equations described in section 4.1. The comparison of simulation results and numerical results obtained from solution of the analytical model in terms of average delay and average number of stored in station buffer are depicted in Fig. 5 and Fig. 6. From these figures, the two results are almost in total agreements. The differences between the analytical and simulation values came from the approximation done on the analytical equations.

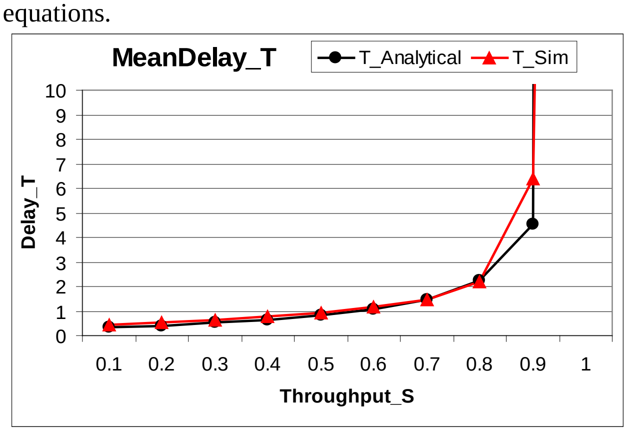

Fig. 5 Mean total delay versus Throughput

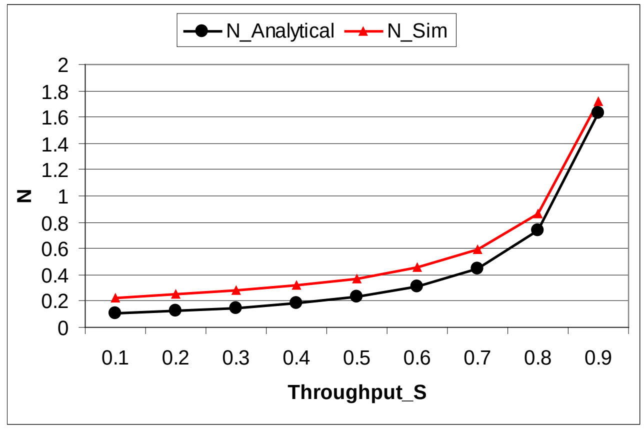

Fig. 6 Average number stored in station buffer versus Throughput

4.3 System performance at different conditions

Effects of increasing the total number of stations: the effect of increasing the number of stations on the performance of polling networks is shown in Fig. 7 and Fig. 8. As we expected, increasing the number of stations will increase the cycle time, and thereby increasing the waiting time of a packet. Consequently, increasing the waiting time will increase the average number of stored packets at station.

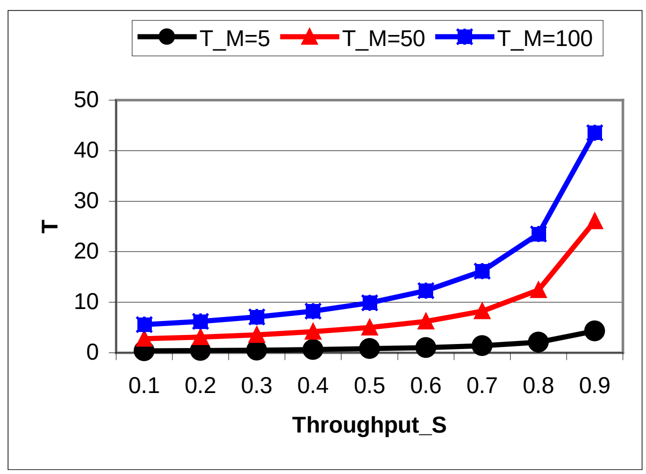

Fig. 7 Mean delay versus throughput at different number of stations

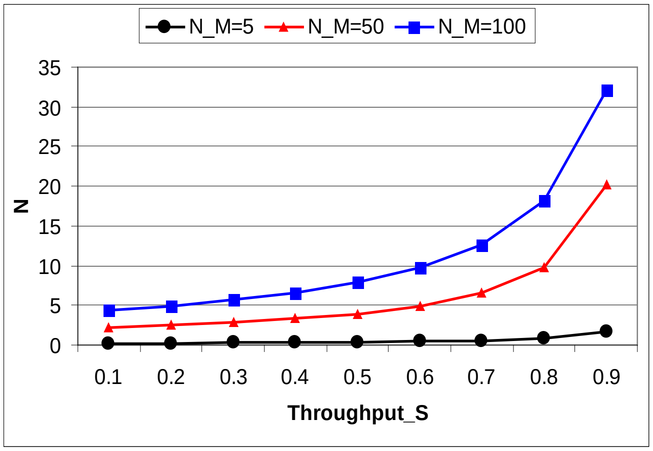

Fig. 8 average number of packets stored at a station versus throughput at different number of stations

Effects of increasing the walking time: the effect of increasing the walking time on the performance of polling networks is shown in Fig. 9 and Fig. 10. As we expected, increasing the walking time will increase the cycle time, and thereby increasing the waiting time of a packet. Consequently, increasing the waiting time will increase the average number of stored packets at station.

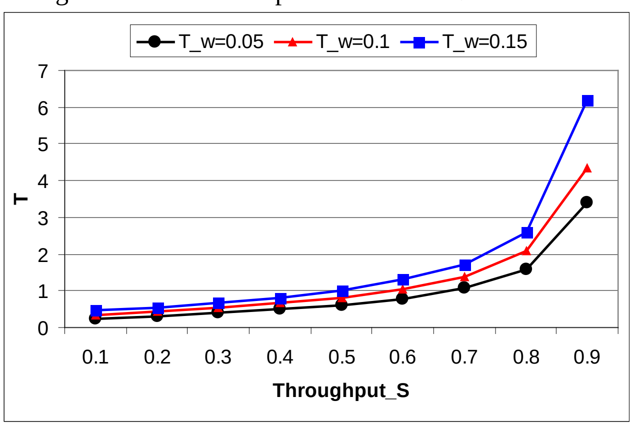

Fig. 9 Mean total delay versus throughput at different values of walking time

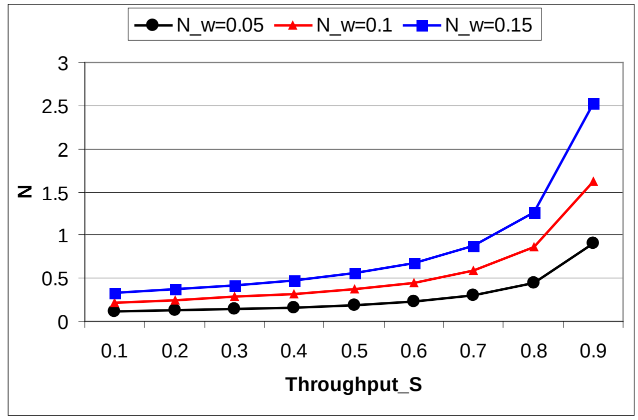

Fig. 10 average number of packets stored at a station versus throughput at different values of walking time

Average Transfer delay and average cycle time: The total time required to poll each station and return to the starting station in the polling sequence is called cycle time. Fig. 11 shows T and Tc/2 versus S with different walking times. This figure verifies that Tc/2 is an excellent approximation for T if Mw is sufficiently large.

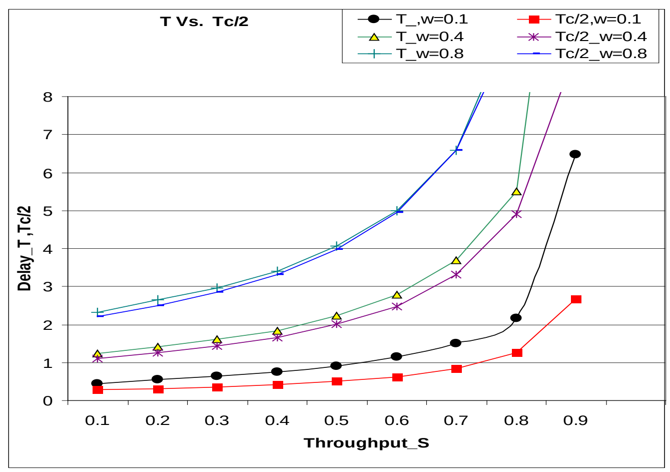

Fig. 11 average transfer delay and Tc/2 versus throughput at different values of walking time

4.4 Exhaustive service versus K-limited service

It is well-known that in a polling system, exhaustive service has the highest efficiency, 1-limited service has the lowest efficiency. But this issue is correct in certain conditions. In this section the performance of polling networks using exhaustive service policy versus K-limited service policy in terms of average transfer delay are compared. Using the parameters: Arrival rate=0.4, M=5,w=0.1 ms, we show how the mean transfer delay vary with parameter K . As shown in Fig. 12, the performances of two service policies are the same for the case of low and medium traffic load. For high traffic load, the transfer delay of K-limited service policy is less than exhaustive. However, when the parameter K is large enough, it functions nearly like the exhaustive service.

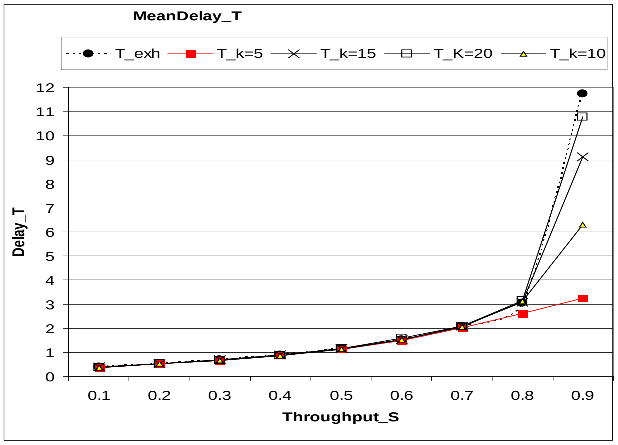

Fig. 12 Transfer delay versus throughputs for Exhaustive and K-limited

5. Conclusions

In this paper we have modeled the performance of distributed poling networks under exhaustive and K-limited services at certain conditions. From examination of the equations and plots given in previous sections, we can make some comments on the design of polling networks. In fact, it is important to keep average of transfer delay and average of stored packets per station as small as possible. So, to do that, the number of stations should be restricted when the walking time is large and, correspondingly, if large number of stations is required, we should try our best to keep the walking time as small as possible.

Also, both average of transfer delay and average of stored packets per station increase with throughput. Thus, as throughput increases, the performance in terms of delay will decrease, and more storage is required at the network stations.

In case of low and medium traffic load environments, the exhaustive and k-limited service disciplines are almost the same. However as throughput increases, k-limited service disciplines will provide more fairness than exhaustive. But as K becomes large enough, the performance K-limited discipline approaches the exhaustive.

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