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ANALYSIS OF PERFORMANCE PARAMETERS FOR WIRELESS NETWORK USING SWITCHING MULTIPLE ACCESS CONTROL METHOD

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The developments of wireless networks have directed to search for opportunities of a broad diversity of improved and new networking contributions. Wireless Asynchronous Transfer Mode (ATM) is a non-synchronous or random mode of transferring information. The advantages of circuit switching include dedicated connections and guaranteed traffic parameters and the benefits of packet switching are the efficiency at the physical layer and a more cost-effective design. ATM is the only protocol that offers the best of both communication methods. Although the Variable Bit-Rate (VBR) transmission presents a promising prospective of stable data quality, it is usually accompanied by network traffic overload and cell packet loss, which extensively weakens that potential. This work overcomes these concerns by developing a switching-based multiple access control model to improve the data transmission performance of wireless ATM. Therefore, this work discusses the effectiveness of the developed approach to minimize the cell packet losses and network traffic overload in wireless ATM. Three control access is processed; polling, token passing, and reservation algorithms for collision avoidance. The reservation stage reserves the data before sending, which includes two timeline intervals; a fixed-time reservation period, and variable data transmission interval. Using OPNET 10.5, the results show that the presented switching-based multiple access control model can achieve a throughput value of 98.3 %, data transmission delay of about 40.2 ms, and 0.024 % of packet losses during data transmission between the source and destination. It is demonstrated that the introduced method effectively transmits information without creating any network complexity and delay

Keywords: Wireless Network, Wireless Asynchronous Transfer Mode (ATM), video data, OPNET simulation tool

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1. Introduction

One of the key knowledge leading to significant improvement of the performance parameters of a network is by optimizing the delay, loss, and throughput of that network [1]. This will allow several users to broadcast packets simultaneously without collisions [2]. Asynchronous Transfer Mode (ATM) is a random, or non-synchronous, mode of transferring information [3]. ATM is a cell switching and multiplexing technology that combines the benefits of circuit switching with the benefits of packet switching. The benefits of circuit switching include dedicated connections and guaranteed traffic parameters and the benefits of packet switching are the efficiency at the physical layer and a more cost-effective design. ATM is the only protocol that offers the best of both communication methods. In its physical design, ATM is a packet switching technology; however, using advanced software, ATM allows the creation of a virtual circuit switched network. ATM networks have efficiency and cost-effectiveness at the physical layer, and at the same time they appear to the end users as dedicated connections between each device with guaranteed levels of service [4].

These different types of multimedia all require different levels of service to support communication. Some need more bandwidth, some need less delay and others need to prevent loss of data. ATM is designed to meet all these communication needs. Additionally, before ATM, communication data was separated on one network. Voice and video require three different networks to support different types of communication. ATM is designed to meet all these communication needs, as well. Quality of service, or simply QoS, is important not just in relation to the bandwidth needs of applications, but for different users as well. Some protocols are used in the LAN and others in the WAN. Different levels of bandwidth are also dependent on which protocol is running.

ATM was developed by the WAN telecommunications industry as a new and improved way to support different types of traffic, such as voice, video and data, across the WAN [5]. It was only during the development of ATM that it was seen as a protocol that could be used for all networks not just the WAN, but the LAN and MAN too. So, because it can support different types of traffic, ATM is a very flexible protocol that can detect different classes of traffic and assign them the appropriate quality of service. Voice gets one level, video gets another and data a third yet all co-exist on a single wire. Fig. 1, *a* gives a good view of the problem with existing networks that don't use ATM.

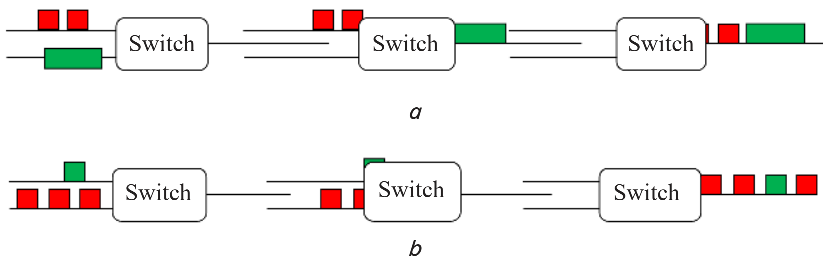

Fig. 1. Data transmission: *a* — without ATM; *b* — with ATM protocol

In this example, the low-priority traffic arrives at the switch first. Since switches work on a first-come, first-served basis, the other traffic, even though it has higher priority, must wait. Prior to ATM, the only way to deal with this problem was to increase the bandwidth, which made the delay shorter. But this did not resolve the underlying problem. ATM uses cells instead of frames, and a cell is a small fixed-length packet of data. Frames, in comparison, have a variable length. Using fixed-length packets avoids the previous situation in which the packets are processed on a first-come, first-served basis. As it is described in Fig. 1, *b*, one large packet is fragmented into several smaller packets, called cells. Now, when the group of low-priority cells arrives at the switch, they are processed one at a time. When the high-priority cell arrives, the switch is able to interweave this cell with the previous traffic, so there is only minimum delay. This is the great advantage of ATM, where all traffic is of the same size, and all traffic can be prioritized. ATM allows many different types of traffic to be supported on a single network infrastructure.

Small cells reduce the delay caused by other traffic that is waiting for access to a network. If cells were large, then the first train scenario would still occur, even with ATM. The fixed-size cell is very important because it can calculate something called deterministic delay and determine the delay or estimate how long it takes for traffic to go from one side of the network to another. This is not very important for data traffic.

ATM networks are different from the typical Ethernet networks we have already discussed. For one thing, ATM uses special signaling between switches, and this is something not found in Ethernet. This signaling, or communication exchanged between ATM devices, is ATM's way of sharing information across the network. Two types of signaling are used in ATM communication. One type, called User to Network Interface, or UNI signaling, allows end stations to communicate with their local switch. Another type of signaling, called Network to Network Interface signaling, or just NNI signaling, supports communication between switches. Here's a large ATM network. Some of the ports are configured to communicate with UNI signaling, and other ports are configured to use NNI signaling. NNI signaling is often written as PNNI, with "P" standing for Private. PNNI is a special kind of signaling used within corporate networks. Corporate networks are considered private networks compared to the public networks (like the public phone system) that telecommunication companies build [6]. An example of ATM networking is shown in Fig. 2.

The final ATM integration protocol we will discuss today is called Multi-protocol Over ATM, or just MPOA. The goal of MPOA is to combine the best features of LANE, CIP and ATM routing functions into a single protocol [7]. One of the limitations of LANE is that it acts as a layer two protocols and requires standard routing to connect two devices in different ELANs. CIP, on the other hand, is a layer 3 function. MPOA creates one large ATM network. Layer 2 communication uses LANE and ELANs for communication. Layer 3 communication uses a capability like CIP, but this time, all layer 3 protocols are supported, not just IP, as with CIP. MPOA also uses an additional routing capability called Next Hop Resolution Protocol, or NHRP. What NHRP does is determine and configure the best path to direct through an ATM network by bypassing any routers that might delay the traffic. Network managers who use ATM are closely following the developments in MPOA, as it is still a very new protocol.

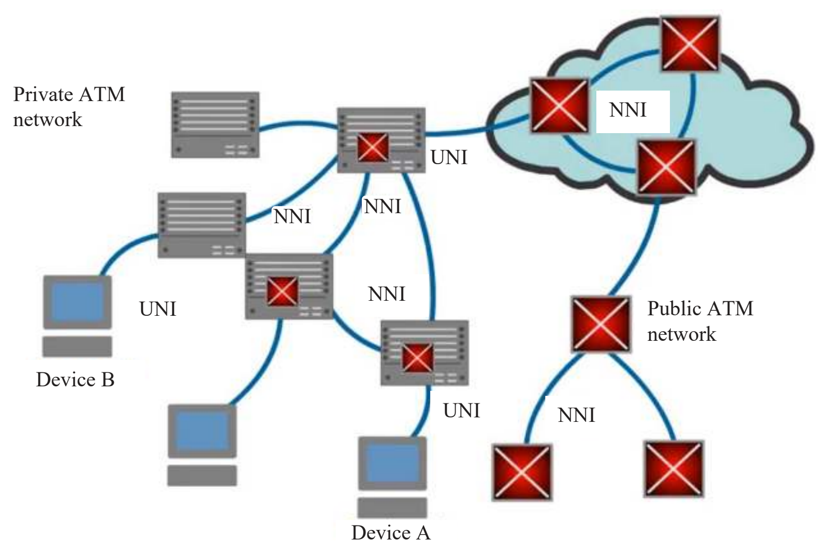

Fig. 2. ATM communication

Therefore, the studies indicate the importance of analysis towards improving the performance parameters of a network by optimizing the delay, loss, and throughput of wireless networks, such analysis is considered in this study.

2. Literature review and problem statement

The study [8] addressed MAC-layer misbehavior in multi-channel wireless networks by improving the security and spectral efficiency of channel access mechanisms in multi-channel wireless networks. Selfish users can modify MAC-layer protocol parameters to get an unfair share of network resources while remaining undetected, according to the author. The author also identified potential MAC-layer misbehavior, assessed its influence on network performance, and devised detection and mitigation strategies that effectively reduce misbehavior gains. Additional activities, such as cooperative spectrum sensing and spectrum management, are implemented using these protocols. The given technique removed in-band and out-of-band control signaling, increased spatial channel reuse, and produced much higher throughput and lower delay as compared to the prior art. In addition, the author looked at DoS attacks against the channel access method. Due to the usage of a default control channel, the author concentrated on reactive jamming attacks and demonstrated that most MMAC protocols were vulnerable to low-effort jamming. The investigation found that, despite the efforts of the jammer, the new protocol maintains communications under high load conditions. The paper [9] investigated a cell-loss recovery strategy for ATM virtual circuits (VCs) that is a hybrid of automatic repeat forward/request error control (FEC/ARQ). A simple single-parity code was used for FEC, and a Go-Back-N ARQ was added on top of it. The hybrid scheme's throughput efficiency and reliability study were both given. The authors evaluated the interaction impact of network characteristics (traffic intensity, number of transit nodes, ARQ packet length, etc.) on performance during this process. Their research resulted in a strategy for reducing the size of the FEC code for a particular network specification. Although, this study discussed two different schemes to apply FEC on alleviating the issue of packet losses, it didn't address other network parameters like transmission delay and throughput. Some modifications in the ATM transmission process are done in [10] to overcome this problem, with forehand and reliable signaling transmissions. This publication offered an overview of signaling transmission evolution. From a signaling standpoint, migration to NGN was investigated. The protocols for NGN signaling and the transmission needs that go with them have been identified. Although the study examined the signal strength to help to maximize the overall signaling transmission process, the network traffic overload wasn't discussed in detail as a significant property of wireless asynchronous traffic mode. On the other side, the study [11] transferred fixed wireless controller area network (CAN) using WATM air-protocol and OPNET Modeler. The study results showed that various types of CAN messages transport different data basis traffics. The system carried various CAN messages to resolve the quality of service issues, but their broadcast delay time was within 100 msec, which is relatively high.

Despite the various advantages of Wi-Fi-based access networks, such as the use of low-cost commodity hardware, operating in unlicensed spectrum, and ease of deployment, they suffer from performance and reliability issues caused mostly by electromagnetic interference. When there are mobile clients on the network, the issues get worse. The study [12] focused on two critical concerns: minimizing interference and facilitating client mobility, by proposing cross-layer solutions that successfully handle these difficulties by utilizing information available at the link layer and network layer. The author presented four designs. The first is a lightweight opportunistic protocol called Deflect, which runs beneath the routing layer and protects end-to-end routes from short-term link quality reduction. Deflect achieved this by combining a low-overhead path switching algorithm with a passive connection quality evaluation technique. Second, because Wi-Fi networks have a limited number of non-conflicting channels, interference between surrounding access points operating on the same channel can be severe in dense WLAN installations, resulting in network capacity reduction. As a result, this paper introduced Contour, a dynamic transmit power control strategy that enhances spatial reuse while avoiding the link asymmetry issues that come with using different transmit power levels in a network. Third, a rogue person can cause interference on a channel, effectively jamming all communication. This paper suggested a Channel Hopping protocol to improve the resilience of Wi-Fi networks to jamming assaults, where the hopping parameters are tuned to maximize the possible throughput in the presence of a clever jammer that is aware of the employment of a hopping protocol. Finally, client mobility disrupts connectivity for a short period of time. In mesh networks, this is more difficult. The author created the iMesh mobility management architecture, which uses link-layer feedback information to track the client's location and instantly adjusts the routes on the mesh network for mobile clients.

The papers [13, 14] analyzed the improvement of packet loss reduction and handover latency in the wireless network employing scanning algorithm. This algorithm helps to minimize the handover latency and reduced the packet loss effectively, and maximizes the packet transmission rate, but the study didn't show the graphical representation of the achievements as well as the transmission time delay was not investigated. The research [15] introduced an efficient Delay-tolerant networking by utilizing a buffer scheduling technique to help resolving network congestion and overload problems of a wireless network. In the same context, the study [16] made research on vehicle delay tolerant networks, the authors investigated a scheduling strategy and energy-efficient routing. They used replication and forwarding methods to try to identify efficient routing strategies optimizing overall network efficiency to forecast the unknown network environment such as traffic pattern in various network scenarios using the Nash Q-learning methodology. By learning and forecasting the network environment, their findings enhance energy efficiency and data delivery ratios. A sufficiently flexible technique for clustering WSNs was proposed in [17], incorporating various innovative or promoted metrics such as the cluster head selection algorithm, cluster optional reconstruction, interested data transfer, and the multiple-path routing protocol. All of these techniques were used to enhance the overall system's energy savings. By flexibly switching the state of several sensor nodes in different techniques, an acceptable MAC protocol for this mechanism was proposed. The simulation results revealed that the suggested MAC protocol is suitable for clustering WSNs and has good flexibility, energy efficiency, and scalability characteristics.

To overcome the above issues, this approach proposes a scheduling algorithm to minimize the overhead ratio and maximize the whole packet transmission ratio. In accordance with different study views, the transmission rate, congestion issues, and packet loss can be resolved through various protocols or data routing. Relying on these algorithms, the study introduces a multiple access control method with a switching protocol for minimizing packet losses, traffic overload, and optimizing the whole data transmission technique.

3. The aim and objectives of the study

The study aims to analyze the performance parameters at various traffic values of ATM wireless networks.

To achieve this aim, the following objectives are accomplished:

– to obtain high values of throughput at various traffic values in wireless ATM;

– to reduce the cell loss probability value (CLP);

– to minimize packet losses and data transmission delay whilst data propagation between a source and destination.

4. Materials and methods

In this section, we calculate the delay, loss and throughput of the transmission of a packet. To demonstrate the data transmission process in a network, Fig. 3 shows two PCs networking with a router and switch.

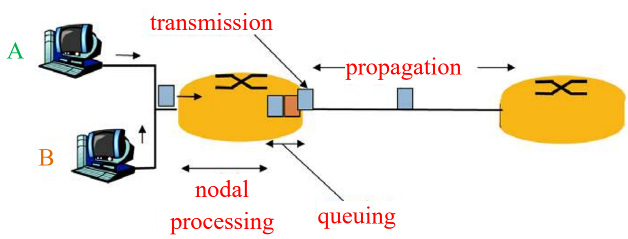

Fig. 3. Two PCs networking with a router and switch

There are four sources of delay that can be given by:

$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}, \quad (1)$$

where d_{nodal} denotes the overall networking delay; d_{proc} represents the delay of nodal processing, which is due to checking bit error, determining output link, and its interval is less than 1 msec typically; d_{queue} represents queuing delay due to time waiting at the output link for transmission and it depends on the congestion level of the router; d_{trans} denotes transmission delay, which is given by ($d_{trans}=L/R$) and depends on packet length (L measured in bits) and link transmission rate (R measured in bps); d_{prop} represents the propagation delay and can be given by ($d_{prop}=d/s$), where d denotes physical link, and s denotes propagation speed (around 2×10^8 m/sec). Trace route program provides delay measurement from source to router along end-end Internet path towards destination [18].

The network loss of packets queue in router buffers, which is combined by the latency or lag, occurs when the packet arrival rate to the link exceeds output link capacity and at packets queue, waiting for turn. Fig. 4 demonstrates the loss due to arriving packets dropped if there is no free buffer.

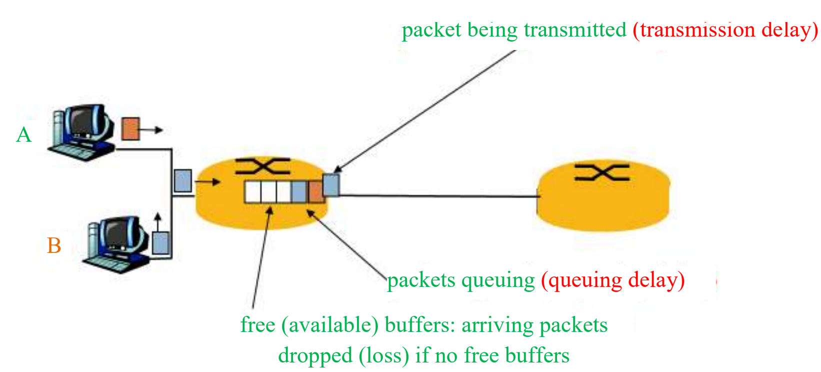

Fig. 4. Packet losses if no free buffers

There are several tools freely available to measure the packet-loss rate (PLR) of a network [19]. However, the considered formula to calculate the packet-loss rate is given by [20]:

$$PLR = \frac{N^{tx} - N^{rx}}{N^{tx}} 100\,\%, \quad (2)$$

where N^{tx} and N^{rx} denote the number of transmitted and received packets.

The throughput of a network refers to the average data rate of message delivery or successful data on a particular communication link. Throughput is calculated in bits/second (bps). The maximum throughput of a network equals the Transmission Control Protocol (TCP) window size by the roundtrip time of the communication data packet. The steps for converting the TCP window size from bytes to bits, dividing the TCP window size in bits by the network path latency, and converting the result from two megabits per second are provided by [21].

$$\text{propagation delay} = \frac{\text{distance between routers}}{\text{propagation velocity}}, \quad (3)$$

$$\text{Round trop time}(RTT) = 2 * \text{propagation delay}, \quad (4)$$

$$\text{Time out}(TO) = 2 * RTT, \quad (5)$$

$$\text{Time to live}(TTL) = 2 * TO, \quad (6)$$

where TO represents the time out that is given by (5). Window size is employed to set up connection-oriented communications. To avoid the overload of network traffic, a check of time to live, propagation delay, round trip time, and time out value are computed [22].

4. 1. Proposed model

We adopt a wireless infrastructure network with many wireless users and a single wireless Access Point (AP). There are no hidden nodes in the network since users are clustered around an AP where they can identify all signals from one another.

After reserving the station, the data is transmitted through the polling procedure, with the controller being chosen to send the message to the secondary station or other stations. The controller is used to broadcast the complete data, which aids with access control. When the secondary station gets the message, it establishes the appropriate acknowledgment to avoid packet or data loss.

Finally, the token system is employed to convey data without causing data loss or control overload. Stations are linked using tokens, which are used to gain access to the next station and deliver data. The stations are connected in a ring form, and acknowledgment is supplied during the data transmission process to guarantee that the data is accepted. The data is transported from source to destination via these three methods, which eliminate overload and collision. The complete WATM working method is explained in the algorithm phases below, according to the discussion.

The switch has a completely interconnected structure with both synchronous inputs and output ports with output buffering in wireless ATM. The switching model, according to [23, 24], consists of a series of cell services, with activities carried out in time slots. The service interval (SI) represents the time it takes to serve an ATM cell, and the service completion (SC) represents the conclusion of the slot (SC). As a result of this discussion, the switch $N*N$ has SI and SC characteristics, with burst workload functions like $f(.)$, $g(.)$, and $h(.)$ being employed for A_n, D_n and Q_n.

In the ATM procedure, the tagged port is used to calculate the loss value. Packet loss is efficiently avoided once the switching and cell loss probability value (CLP) are identified. To optimize the overall information transmission process in WATM, network traffic overload should be controlled when packet loss is eliminated. Multiple access control routing protocol is used to attain this purpose.

4. 2. WATM working process algorithm

Step 1. Gather information in the network space for making data transmission.

Step 2. ATM cells are analyzed concerning service interval (SI) and service completion (SC).

Step 3. The cell emission probability value is computed as follows:

$$ni = a_0 + a_1,$$

$$a_0 = c_k^{mi} * (p_i - a)^k * (1 - p_{i-a})^{mi-k},$$

$$0 \le k \le mi,$$

$$a_1 = c_j^{(N-mi)} * (p_{(a-ai)})^1 * (1 - p_{(a-a)})^{(N-mi-1)},$$

$$0 \le k \le N - mi.$$

Step 4. The ATM cell switching procedure is as follows:

$$A_n = C_r^{ni} * (P_{cell})^r * (1 - P_{cell})^{ni-r},$$

$$0 \le r \le ni.$$

Step 5. The related switch interconnected model is defined as follows, taking into account the ATM cell probability value.

$$D_n = A_n - (Q_{\max} - (Q_{n-1} - 1)).$$

$$A_n > (Q_{\max} - Q_{n-1} - 1).$$

Step 6. After that, a cell loss probability value (CLP) is generated to determine whether or not data has been lost.

$$CLP_n = \frac{E(D_n)}{E(A_n)}.$$

Step 7. The switching model is altered based on the CLP value to prevent data loss and network overload, and congestion is reduced by employing the multiple access control routing protocol.

Step 8. To transmit data using the ARQ process, determine the network, TO, TTL, RTT, and propagation delay values.

Step 9. The ARQ process and sequence number-based data transmission method at the data link layer reduce data and acknowledgment delays.

Step 10. Next, the station status (idle or busy) is determined in order to transmit data utilizing the reservation, polling, and token concepts.

The information is transported from source to destination using the algorithm stages, which eliminate network collision and packet loss. Experiment findings and discussion are used to assess the system's effectiveness.

5. Results of throughput, CLP, transmission delay, packet loss, and network overhead

5. 1. Throughput

The acquired data are listed in Table 1, while the graphical representation of these percentage throughput data is shown in Fig. 5.

Table 1

Acquired throughput data

Number of transmissions	Traffic								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
20	0.98	0.92	0.947	0.97	0.934	0.967	0.972	0.937	0.92
40	0.967	0.976	0.965	0.973	0.936	0.972	0.982	0.956	0.93
60	0.96	0.97	0.983	0.93	0.97	0.98	0.967	0.97	0.97
80	0.973	0.98	0.976	0.97	0.96	0.97	0.98	0.976	0.98
100	0.98	0.973	0.97	0.967	0.98	0.98	0.965	0.96	0.976
120	0.978	0.973	0.968	0.973	0.97	0.975	0.98	0.975	0.98

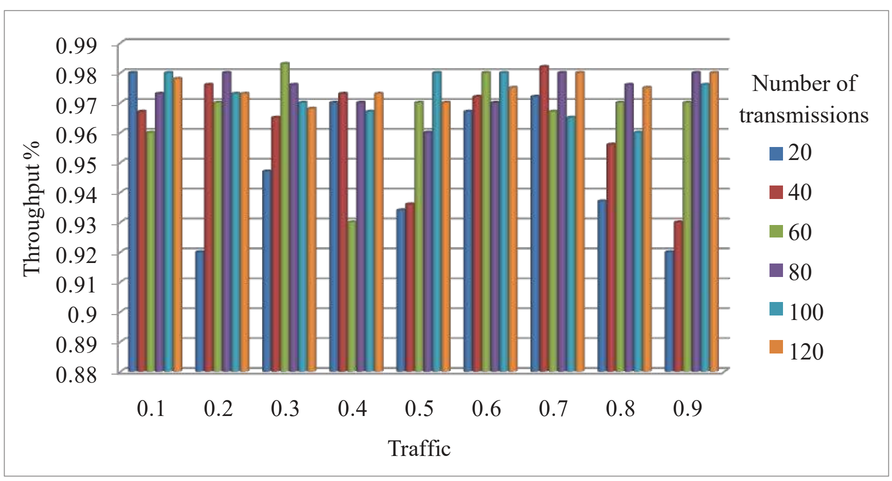

Fig. 5. Percentage of throughput

The presented switching model by adopting the multiple access control method achieves a high value of throughput on various traffic ATM values.

5. 2. Data transmission delay

The efficient calculation of station status, the identification of station reservation, and cell probability loss assist to indicate the correct transmission medium successfully. Successful data of the presented ATM switching model decreases the cell loss probability value. The acquired CLP values are listed in Table 2.

The scheme successfully identifies the number of cells of arrived and discarded data using $CLP_n = \frac{E(D_n)}{E(A_n)}$ that assists to calculate the CLP values precisely. The graphical representation of these data is shown in Fig. 6.

The obtained data delay value is depicted in Fig. 7.

Throughout the process of data transmission, the technique inspects every status of the station, which helps to decrease network congestion. In addition, the process utilizes the reservation and token criteria to broadcast the data without producing much delay.

Table 2

Cell loss probability value (CLP)

Number of transmissions	Traffic								
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
20	0.023	0.018	0.028	0.028	0.026	0.021	0.0189	0.018	0.017
40	0.018	0.0167	0.0165	0.0176	0.0180	0.018	0.0157	0.012	0.027
60	0.027	0.025	0.021	0.027	0.027	0.021	0.023	0.023	0.021
80	0.028	0.021	0.028	0.026	0.026	0.024	0.025	0.028	0.021
100	0.022	0.026	0.0218	0.0254	0.025	0.023	0.021	0.025	0.027
120	0.029	0.027	0.021	0.023	0.022	0.020	0.025	0.023	0.024

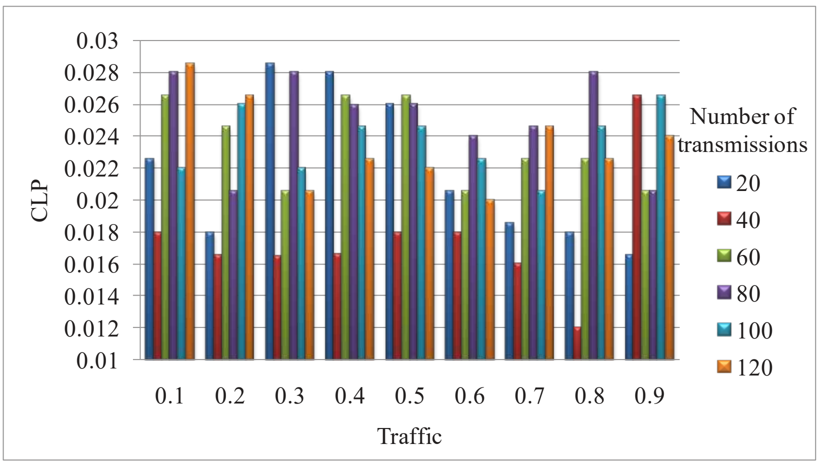

Fig. 6. Cell loss probability value

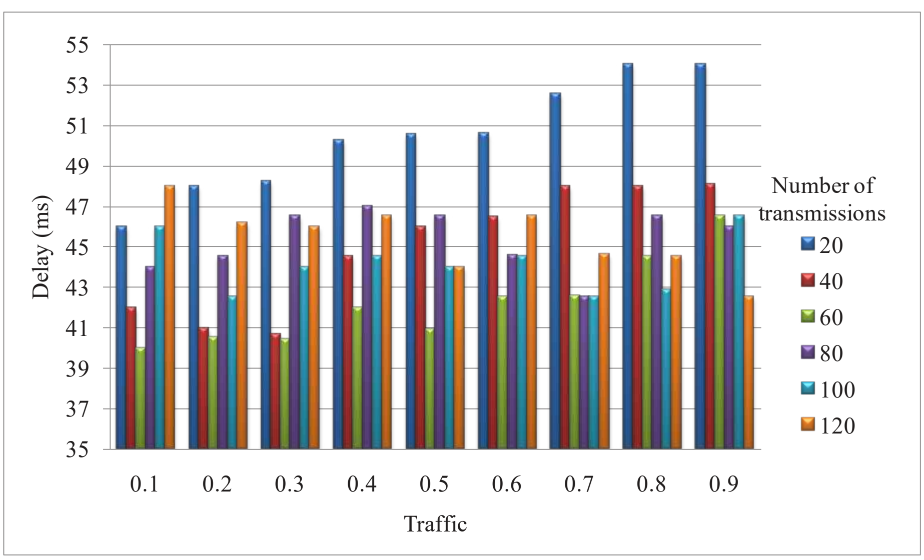

Fig. 7. Delay

5. 3. Packet loss

The obtained result is demonstrated in Fig. 8.

In addition to this, the overall network overhead value is analyzed, and the individual result is demonstrated in Fig. 9.

The presented approach of the switching model by adopting multiple access controls achieved low values of network overhead.

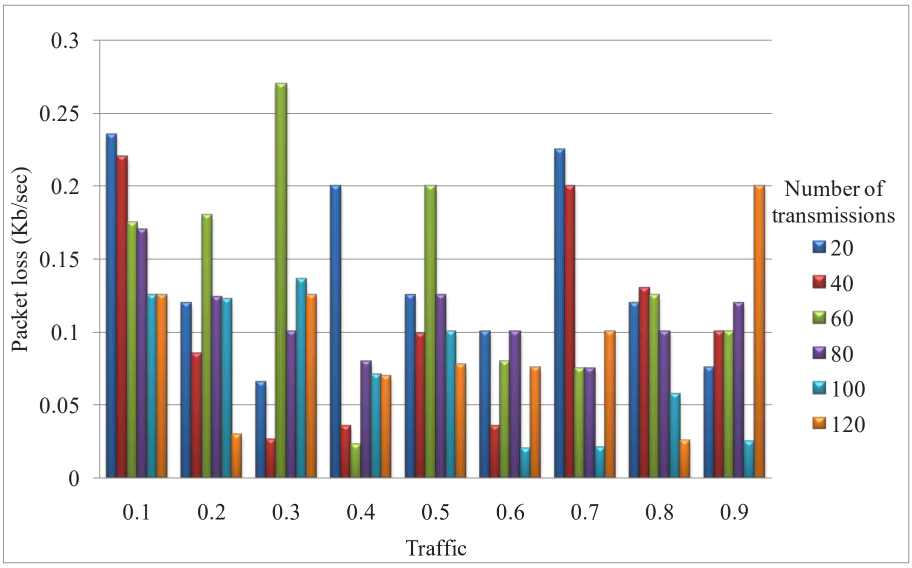

Fig. 8. Packet loss

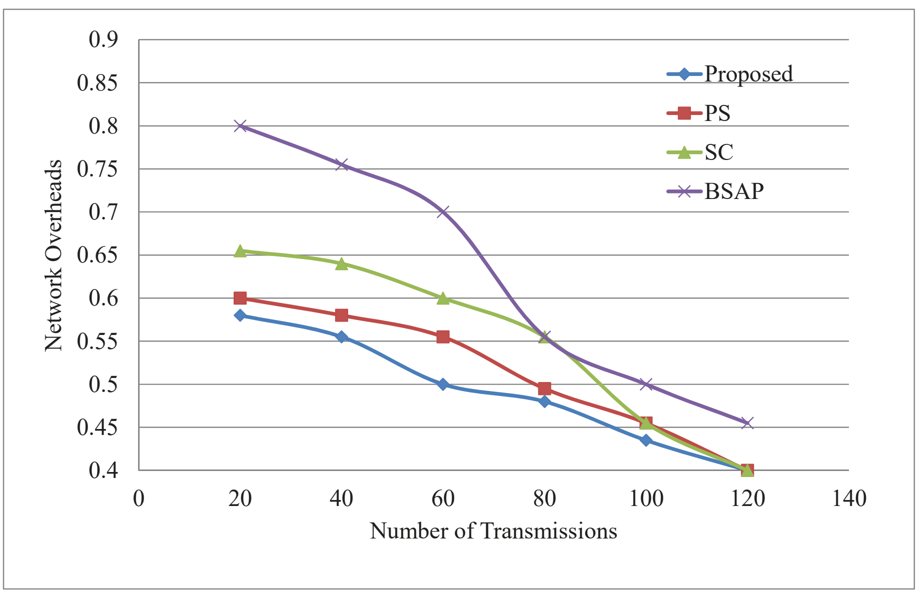

Fig. 9. Network overhead

6. Discussion of the ATM network performance parameters

The presented approach uses the OPNET simulation tools [25–27]. The simulator utilizes the 802.11 g operation mode, data rate 54 Mbps, transmission power 0.005 W, network dimension is 100 m*100 m, 120 number of transmissions and bay networks' Accelar 1050 switch model was utilized. The simulation process is performed around three hours and the simulation running time is approximately 1 min. Using OPNET simulation tools helps to evaluate the system parameters such as system efficiency, CLP value, throughput, delay, overhead network metrics, and packet loss.

Starting with Fig. 5, it is obviously shown that the presented switching model with the considered multiple access control approach achieved 98.3 % of throughput value during data transmission from source to target. Efficient calculation of every input, switching model, and station helped to optimize the data transmission rate.

Fig. 6 demonstrates that the presented switching model approach achieved a 0.00221 CLP value as transmitting data from source to destination with ensuring low CLP values at different numbers of traffic and transactions.

Fig. 7 clearly illustrates that the proposed method got minimum delay during data distribution. Since this method achieved low CLP values, the indication of station status can diminish the whole broadcast delay. We achieved a 40.2 ms delay at 120 transmission systems at different traffic values.

Fig. 8 evidently shows that the proposed method achieved minimum packet loss while source-destination data transmission. The low CLP values help to decrease the whole packet loss. At 120 transmissions, the system guarantees 0.024 % of packet loss at different traffic values.

From Fig. 9, the presented switching model with the considered multiple access control approach achieved low network overheads compared to other methods such as Packet switching (PS) [28], Scanning (SC), and Buffer scheduling algorithm (BSAP) [29].

Each node has a restricted buffer with a maximum of 30 packets by default. A packet can be transmitted or received in one slot. The route destination is set to the simulated roadside access point. Future research will look at the effectiveness of the physical layer as a more cost-effective design with various types of application scenarios. We may also create a Delay-tolerant networking architecture based on application requirements by using relevant network criteria.

7. Conclusions

1. The presented switching model with the considered multiple access control achieved 98.3 %

of throughput value while transmitting data from source to destination at different traffic values of wireless ATM.

2. The results show that the presented approach can effectively lower CLP value for different numbers of transactions and traffic, and improve the data delivery ratio.

3. Because of the minimum CLP values, the presented approach achieved low packet loss and delay values during broadcasting data from source to destination. At 120 transmissions, the system guarantees 0.024 % of packet loss at different traffic values. Based on the analysis, the presented technique efficiently transmits information without producing network delay and complexity.

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