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Using Fuzzy System To Control Cell Multiplexing In Atm Networking

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Abstract

The aim of this research is to design and simulate a fuzzy logic controller (FLC) to control the cell multiplexing in Asynchronous Transfer Mode(ATM) networking , which is a high performance cell oriented switching technology that utilizing of small size packet to carry different types of service for traffic and to show the effect of using the fuzzified variables (queuing message length and the number of inputs) on cell flow rate (control action) on the output of (FLC).The paper presents the previous works, principles of operations, cell multiplexing, principles of fuzzy logic and internetworking with ATM network, the design process of system and the output of simulation. The cell flow rate on the output of fuzzy logic controller (FLC) which has been simulated depends on the input variables, one of them is the queuing message (message length), and the second one is the number of inputs. The simulation of fuzzy controller has been executed by using (MATLAB). In the light of this research, an important conclusion can be drawn, is that increasing of the fuzzified inputs variables means that cell queuing will increasing so the (FLC) will achieve size of packet to be large then the flow bit-rate of cell (control action) will decrease and when the number of inputs decreases that will let to achieve a high flow bit-rate as (M.Q=0.5,N=o.5,the control action (cell rate) =0.5 cells/s) and if (M.Q=0.2, N=0.5, the control action(cell rate=0.77 cells/s).Using parameters such as (**message length and No. of inputs**)as fuzzified variables in controlling cell multiplexing gives a flexible and a high speed responding to sudden changes in selective variables and get bit-rate which reduces time delay for different types of services(text, image, video and audio) which cause to get a high throughput, that is the ***maximum throughput*** under FLC parameters (***with message length and No. of inputs)*** is (562.7Mbit/s) for text message, (568Mbit/s) for image message, (563.4Mbit/s) for the video message and (563.4Mbit/s) for audio message

Keywords: Fuzzy Controller; ATM; Cell Multiplexing.

استخدام المنطق المضبب للسيطرة على نقل بيانات عدة خطوط الى خط نقل واحد في منظومة خط النقل الغير متزامن

الخلاصة

يهدف البحث الحالي الى تصميم ومحاكاة نظام مسيطر باعتماد المنطق المضبب (FLC)السيطرة على نقل بيانات عدة خطوط الى خط نقل واحد الذي يجري في مفاتيح شبكات خط النقل الغير متزامن (ATM) وذلك للحصول على معدل تدفق خلايا (cell flow rate) بشكل كفوء ومناسب . وملاحظة تأثير استخدام المتغيرات المضببه المتمثله(بطول الطابور وعدد المداخل) على فعل السيطره أي على معدل تدفق الخلايا للمسيطر المضبب. ويعرض البحث

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بعض الأعمال السابقه ومبادىء عمل ال(ATM) وعمل نقل خلايا البيانات لعدة خطوط وتحويلها الى خط نقل معلوماتي واحد (cell multiplexing) وتأثير استخدام المنطق المضبب عليها ومراحل تصميم النظام الحالي. ان معدل تدفق الخلايا الخارجة من منظومة المسيطر المضبب (FLC) والتي تمت محاكاتها تعتمد على نوعين من المتغيرات : المتغير الاول هو طول طابور الخلايا (message length) والثاني هو عدد المداخل (inputs). تمت محاكاة النظام باستخدام برنامج ال (MATLAB) . وفي ضوء نتائج البحث تم التوصل الى اهم الاستنتاجات منها ان الزياده في عدد المداخل تعني الزياده في طابور الخليه وبالتالي الزياده في حجم ال(packet). ومعدل تدفق الخلايا (فعل السيطره) سيقل. أما عند تقليل عدد المداخل سيزداد معدل تدفق الخلايا أي فعل السيطره عالي as(M.Q=0.5,N=o.5,the control action (cell rate) =0.5 cells/s) and if (M.Q=0.2, N=0.5, the control action(cell rate=0.77 cells/s). ان اعتماد المنطق المضبب للسيطرة على ال(cell multiplexing) ساهم باستجابه مرنه و سريعه في السيطره على معدل التدفق مع التغير في **عدد المداخل وطول الطابور** وبالتالي الحصول على معدل تدفق يقلل من التأخير الزمني لأنواع مختلفه من الخدمه وزياده في ال (throughput)حيث ان اعظم قيمة له هي (562.7 Mbits/s) للرسالة المكتوبة (568 Mbits/s) للرسالة الصورية و (563.4 Mbits/s) للرسالة الفديوية و(563.4 Mbits/s) للرسالة الصوتية.

1- Introduction

Advances in technologies have led to new networks; each network offers a range of new services to the users. The problem is that the increasing pace of development in applications threatens, to move toward an alternative new technology, this technology is Asynchronous Transfer Mode (ATM) [1] [2].ATM is the most promising technology for supporting broadband multimedia communication services. The advantages of ATM networks are the flexibility to accommodate diverse mixture of traffic which possesses different traffic characteristics and quality of service (QOS) requirements. The ATM technique provides an alternative solution to the problem of integrating different types of service, with widely different bit-rates, through common interfaces and switching fabrics [3].It is a high-performance, cell-oriented switching and multiplexing technology that utilizes fixed length packets to carry different types of traffic [4].ATM is a cell-switching network because its segments and multiplexes user traffic into small, fixed size units called cells. These cells are switched by hardware leading to a communication system with the best efficiency and scalability. The cell is 53 bytes, with 5 bytes reserved for the cell header and the remainder is 48 bytes as a user data. Small cell sizes offer fewer possibilities to error. It has shown that an error in an ATM cell affects only a single bit. Single bit errors can be easily corrected at the receiver by the inclusion of an error code that contains sufficient redundancy to allow the original bit pattern to be reconstructed. Since all the cells of single message travel sequentially by a single path, so if the single cell is delayed in the transmission, the delay affects all the cells of a message equally [5,6,7]. Although ATM networks can support a wide variety of transmission rates and provide transmission efficiency by asynchronous multiplexing, a cell might be lost in ATM switches if cells are excessively fed into the networks. In order to declare their transmission rate as traffic parameters, e.g. Peak Cell Rate (PCR) and Sustainable Cell Rate (SCR),in advance of transmission [3].ATM traffic management is to protect the user and network in order to provide affective allocation of the network capacity for different sorts of applications such as voice, video and data. ATM traffic management can be divided into layers and procedures [8].The traffic that successfully passes through the conformance monitoring functions is multiplexed at different points. In order to achieve statistical multiplexing applications, which have burst of traffic, they may be assigned to the same link in the hope that statistically not all of them will generate bursts of data at the same time; the traffic may be equal or buffered before being transmitted on the link. Although connection admission is performed at a connection setup, congestion in network elements (overflowing in the buffers) can still occur. Congestion control deals the handling of that the cells are discarded in a fair manner and QOS is guaranteed [9, 10].Fuzzy logic (FL) provides an effective conceptual frame work for dealing with the problem of knowledge representation in an environment of uncertainly and vagueness. Among the most successful application of (FL) are the fuzzy logic controllers (FLC) [11, 12]. As consequence, a fuzzy logic has been used in cell switching and multiplexing to optimize the cell servicing sequences and to reduce cell losses.

2-Literature Review

There are some of the published researches on the subject. In the networking literature several control schemes have been proposed. The control policy is often heuristically motivated, based on simple on –off methods as in control algorithms which forward or backward explicit congestion notification are based[13]. The author [14] proposed modeling and simulating of ATM switching techniques to control the congestion at the network switch. These techniques include a connection admission control (CAC) for constant bit –rate (CBR) and variable bit-rate (VBR) service classes. Due to the burst nature of available bit-rate (ABR), virtual basic (VB) is used for coding the congestion control algorithms used in simulation process. The authors [15] proposed a flow scheme for multicast ABR in ATM network. The -control, is designed to deal with a variation in recourse management (RM) cell round-trip time resulting from dynamic drift of the bottle-neck in the multicast tree. The proposed scheme analyzes the system dynamic for multicast ABR. And author in [16] set two algorithms using a (C++) language for ATM networks composed of three computers at transmitting and three at receiving connected with two ATM switches, one is the algorithm which simulates the feedback mechanism using(explicit rate marking), and the other simulates new developed method combined feedback mechanism using (explicit rate). The ATM Forum has accepted a rate-based flow control proposal whose main goal is to define a flexible framework for congestion control.

The authors [13], set fuzzy explicit rate marking traffic flow control algorithm for a class of best effort service, known as available bit rate (ABR).The flow rate is calculated by the fuzzy congestion control module with monitoring the average ABR queue length and its rate of change. The other in [17] studied the possibility distribution of cell loss as a function of the number of calls per class, by a fuzzy inference scheme based on the observed data of Cell Loss Ratio (CLR).The authors in [3] set to use a fuzzy logic system (FLS type2) to control CAC, which can handle linguistic uncertainties. The linguistic knowledge about CAC is obtained from 30 computer network experts. The scheme proposed in this research is substantially different from the ones seen in the literature above in the sense that different fuzzified parameters have been used in the design of the control algorithm of cell multiplexing in ATM, which are called ***message length and no. of inputs*** to get an effective control. In the calculation of the control action (cell rate), the scheme monitors both variables (***message length and no. of inputs***) .These two variables (parameters) provide some form of prediction for the future control action (bit rate). Thus, the scheme could be expected to be more effective than schemes using feedback based on the queue length threshold, queue length, the rate of change the queue length alone, or queue length and its growth rate. Additionally, the scheme provides bit rate, which reduces time delay for different types of services (text, image, video and audio). One could expect that this method will be robust with respect to cell multiplexing uncertainties and system should be expected to meet the basic congestion requirements of being applicable in the presence of high priority cell flow rate in a network. .Also, one of the critical deficiencies of the schemes described above is that they do not avoid the cell losses by the control on the cell multiplexing in ATM networks.

3-Multiplexing

ATM is a connection oriented switching technology meaning that a connection setup is required prior to transfer of calls. It identifies a path through that on provide the required service (virtual channel connection Va), which has a chain of local identifiers each used at a switch Virtual Channel Identifiers (VCIs).Each input port to switch uses its own private set of VCIs, and it is used to input index into its routing table to find the next hop output, as shown in fig (1) [13].ATM switches provide both switching and multiplexing. Switching is based on a switching (routing) table shown in fig.(1) that is implemented in hardware for permanent virtual circuit (PVC) networks or stored in RAM for switched virtual circuit (SVC) networking [8,17].Fig(2) shows the concept of VPC switching. In this type of switching a channel from one virtual path (VP) may pass into another VP[13].The general structure of ATM switch shown in fig(3).An ATM switching changes the VPI/VCI in each cell it handles. Inside each switch there is a routing table which specifies how the hardware will forward cells. Each entry in the table corresponds to a possible VPI/VCI for a given port; the switch uses the VPI/VCI in an incoming cell to locate an entry in its routing table. In multiplexed system devices share the capacity of one link to many [7]. Signals are multiplexed using two techniques:

1- Frequency Division Multiplexing (FDM).
2- Time Division Multiplexing (TDM).

The present research concentrated on (FDM).FDM is analogue techniques that can be applied with the bandwidth of a link that is greater then the combined bandwidth of the signals to be transmitted. In FDM; signals generated by each sending device modulate with different carrier frequencies. These modulated signals are then combined into a single composite signal that can be transported by the link. Carrier frequencies are supported by enough bandwidth to accommodate the modulated signal.

4-The FDM process

Fig (4) is a conceptual Frequency-domain illustration of multiplexing. FDM is an analogue process; it is using telephones at the input and the output devices. Each telephone generates a single of a similar frequency range. In side the multiplexer, these similar signals are modulated onto different carrier frequencies (f1, f2, and f3).The resulting modulated singles are then combined into a single composite. Signal that is sent out over media link that has enough bandwidth to accommodate it [7].

5:Traffic Control in ATM using fuzzy systems

An application negotiates a traffic contract with the network for each VC.The "traffic contract is an agreement on the behavior of traffic and the level of service category. Any application using an ATM network maps the VCs into an appropriate ATM layer service category. A service category defines the expected QOS class and also specifies the expected behavior of the traffic generated by the application (traffic descriptors) [8].Fuzzy system is a fascinating area of research because it does a good job of trading off between significance and precision, some that humans have been managing for a very long time. Uncertain, in consistent and in complete nature of human knowledge makes it difficult to deal with it on computer. To handle the uncertainty, fuzzy logic has been proposed. With fuzzy logic, if-then style rules can be a powerful to represent knowledge in readable way and it makes system more flexible [12, 18].

6:The Fuzzy Cell Multiplexing Control

Fig (5) shows the block diagram of fuzzy cell multiplexing controller and its relationship with integrated ATM.

<u>The process flow for the fuzzy cell multiplexing controller starts as follows</u> :

An input is determined which is represented in two variables (message length and No. of inputs), then the variables are fuzzified, these values are converted to their fuzzy representations. Also, these values execute all the rules in the rule base, which have the fuzzified input in their premise, resulting in a new fuzzy set representation for each output variable. Centroid defuzzification is used to develop the expected value for each of these output parameters. The output value (flow rate correction) adjusts the state of the (FLC).

7:Designing the fuzzy cell multiplexing controller

There are five fundamental stages in the construction of the proposed model:

First: Selecting the performance (control action).

The (FLC) is supposed to achieve a cell multiplexing using two main variables to calculate the explicit flow rate: 1. Number of inputs (N). 2. Message length (Q). Number of inputs (N) means that the number of data links directed to the same VP or VC at the same time and it changes either by increasing or decreasing. The message length (Q) means the No. of cell per message. The FLC output is a flow of explicit rate of cells at link (FER) that carried information from source to its destinations. In this scheme, it has been supposed to apply a FLC on QOS category, so the traffic parameters used are shown in table (1).

A boundary of message length has been chosen in proposed design, where the maximum length of message is 1024 cells and the minimum length of message is 50 cells, it can do scaling for these variables for simplicity. Another variable is the no. of inputs (links that carry the different data to put in on same channel at the same time).design of a proposed FLC involved section of switchable mathematical representations for rule-base, deffuzzication operators, fuzzy implication functions, and shape of membership functions among a rich set of candidates. The two variables have been used to calculate an explicit flow rate. Based on these two variables (inputs and the linguistic information stored in the rule base), FLC computes the functional flow rate (FERE(0,1)) and explicit rate(ER=FFR* link cell rate) for the sources feeding the ATM switch. If, within the current control interval, the ATM switch receives an RM cell traveling to the stream nodes along the relevant VC, it examines the ER field of the cell and if the rate is greater than the calculated flow rate, it modifies the ER field with the calculated value and retransmits RM cell.

Second: Defining the control surfaces (fuzzy sets).

To build a controller representing this relation ship, the variables have been decomposed into a number of fuzzy control regions called (fuzzy sets). A fuzzy numbers (Linguistic variables) are created by approximating a numeric value, such as about(Too short, Too Long,…..) and (Small, Large) which take the form of triangular fuzzy sets. Fig. 6(a) and 6(b) illustrate the linguistic variables as a fuzzy number placed on the domain of the variables. Finally, the output variable is also redefined into a set of fuzzy regions as shown in Fig. 6(c).

Third: Constructing the relationship between input and output spaces (rules).

The (FLC) can be conceived as non linear controller of which the input-output relationship can be expressed by using a small number of linguistic rules of rational expressions [19]. There are few possible ways for obtaining the linguistic rules of a (FLC). These rules are formed meeting the forms and behavior of input variables and output. After isolating the control features of the system and decomposing each variable of fuzzy sets, the conceptual model is completed by writing the *production* *rules* describes the action taken on each combination of control variables.

The proposed system FLC is (a two-by- one) control system. That means there are two control variables (message length Q and no. of input N) and one solution variable (control action or the cell rate). It is often convenient to think of such control system, as a matrix of actions in an M*N array. The fuzzy states of one control variable from the horizontal axis, and the fuzzy states of other control variable form the vertical axis. At the intersection of a row and column is the fuzzy state of the solution variable. Table (2) shows the rule base table of the proposed system. These rules are taken to execute the FLC simulation to observe the output flow cell rate

If Q is too short and N is small then R is sharply fast.
If Q is too short and N is medium then R is sharply fast.
If Q is too short and N is large then R is fast.
If Q is short and N is medium then R is fast.
If Q is short and N is large then R is normal.
If Q is medium and N is small then R is normal.
If Q is medium and N is medium then R is normal.
If Q is medium and N is large then R is slow.
If Q is long and N is small then R is normal.
If Q is long and N is medium then R is slow.
If Q is long and N is large then R is slow.
If Q is too long and N is small then R is normal.
If Q is too long and N is medium then R is slow.
If Q is too long and N is large then R is sharply slow.

<u>Fourth: Running a simulation of the FLC model</u>.

A fuzzy logic controller, like all fuzzy system, is essentially a parallel processor. All rules with any truth in their predicates fire and contribute to the fuzzy set region being built to represent the system action (solution variable or control action). The rule base is fine tuned by observing the progress of simulation. The tuning can be done with different objectives in mind since the tuning of fuzzy rules is intuitive, and can be related in simple linguistic terms with user experience, it should be a forward straight matter to achieve an appropriate balance between a tolerable end –to-end delay, and an increase in throughput. In present research, ***the message length and No. of inputs*** have been taken. Each rule finds a membership grade for ***message length and No. of inputs*** in the corresponding regions. Fuzzy controller rules specify a general region of control _the actual degree of control is determined. In fact a fuzzy rule such as:

If Q is too short and N is small then R is sharply fast.

Is interpreted as "to the degree that the message length is in the region ***too short*** and No. of inputs is in the region of ***small***, the action of system is in the region of ***sharply fast"***. The intersection of the actual reading (a long the domain or horizontal axis of the fuzzy set) and the surface of any particular fuzzy set tells us where in the region a reading lies. Fuzzy controller uses standard **fuzzy *inference techniques- the minimum inference method*** is used. The minimum degree of membership of the two truth values for all the predicates in a rule is used to form the truth of the predicate,

P truth = min (v1, v2, v3,… vn)

V: truth value.

In present research, the simulation has been done by using a collection of fuzzy regions to get more flexibility of size of the packet out of switching (multiplies) when the number of inputs are large, then the packet size of output will be large and the rate of packet will be high. When the numbers of inputs are going to be less than the packet size, it will be less and the packet flow rate will be less. The transient performance is studied. The response of the controller is considered when the load on the network changes suddenly. Fig (7) shows the queuing model used during the simulation, multiplexing and servicing constant bit rate (CBR), variable bit rate (VBR) and available bit rate (ABR) with their queues in ATM switches 128,128 and 1024 cells long respectively [13]. But our simulation has been used in ABR terminal generates traffic based on a 3-state model see fig. (7) for model and table (3) for selected parameters. The figures from (8 to 11) represent windows of MATLAB works of the simulation. The figures show the simulation process of cell multiplexing. Fig. (9) represents an input variable (message length) as membership function, the range of membership function has been divided from Too short (Tsh), short (Sh), Medium (MED),Long(Lo) and minus long (-Lo). Fig.(10) represents the second variable (No. of inputs).This variable has been represented in rang between short (Sh) and long(Lo) as membership function. These two variables give another output variable which represented in cell rate as a membership functions shown in fig.(11).

Fifth: Performance Analysis and Discussion:

Fig.(12) to fig.(16) show how the FLC works and how the control action output (cell flow rate cell/sec) looks after a number of rules are fired. Much iteration has been done to get a cell flow rate for each iteration depend on changing input variables (***message length and number of input links***).Fig.(12) represents the relation between cell rate and message length of fuzzy multiplexing control. Fig. (13) shows the control action (cell rate) from rule viewer for message length = 0.5, No. of inputs = 0.5, the other figures also show the control action (cell rate) for another value of variables.

a. Performance analysis

The proposed system has some parameters that need to be calibrated of every time, the most important of these performances is:

1.Transmission Time Delay (TTD)

In communication, one of the most important parameters is (TTD) in transmitting a message and receiving it [20]. The Transmission Time Delay can be calculated from equation (1) for one cell.

TTD=Data Size/ Bit-Rate … (1)

Data Size = cell = 53 bytes

= 53 * 8-bit = 424 bits

The actual bit rate for ATM transmission varies from (155.52) Mbit to (622.08) Mbit, due to the changing of number of input of overall categories of QoS (CBR, VBR, and ABR). The transmission time delay can be calculated from equation (1) for different multimedia services. To calculate the transmission time delay and other related parameters for ATM network using the proposed simulation with fuzzy control system, it has been supposed that there are different multimedia services which could be transferred via our system, such as (video, image, text and audio). And two variables (Q and N).Thus, the message size has been taken upon the source and destination as examples for these multimedia communication services. Fig.(17) and table (4) represent the changes in transmission time delay for (one cell, text message, image message and video message) due to changes in bit-rate. From these curves and table, it has been found that changes in bit rate of a message in ATM network cause changes in (TTD) for different communication services, it has been shown that the message size is different so it has been obtained time delays for each type at message. For these curves and table (4), it has been found that, for text message the size is (204 Kbytes) so, the (TTD) is very small. But, for image message, its size is (426 Kbytes) so (TTD) will increase a little more, for video message, it is shown that (TTD) is very large due to the video message size and for audio message; its size is (9.15 Mbytes), the time delay is between the time delay for image and video messages. From all results above, it is shown that when the bit-rate is small, the time delay is very large and vice versa .the results show that the time delay is very limited in proposed system.

2. Throughput calculation

Throughput rate is defined as a number of information bits (users data) to the total time required to get these bits. The throughput rate can be calculated by using the results obtained from the transmission time calculation [21] as follows,

Throughput = No. of information bits / total time required to get these bits . ……..(2)

From equation (2) the throughput has been calculated for different services such as (text, image, video and audio) as shown in (Fig.18), this figure showing that the present FLC for cell multiplexing provides effective control, achieving higher throughput.

3. Efficiency Calculation

The efficiency of the system is defined as a number of the useful information bytes divided by the total number of bytes. So the efficiency can be calculated by the following from:

Efficiency = message length / message length + bytes of headers . …….(3)

Message length = User data
Bytes of headers = headers of cells
For one cell in ATM which is fixed:
Message length + Protocol overhead (Header) = 53 bytes for one cell.

To calculate the message length with the headers (protocol overhead), the number of cells in each message, must be known, this can be achieved by dividing the message length by 48 bytes, then multiplying the number of cells by (53 bytes), So :

For example; the efficiency for transmitting audio message has been calculated, the message length for audio is taken from table (4), so, to obtain the results:

Audio message size = 9.15 Mbytes
9.15*10 /48 = 190625 cells in audio message without headers
190625*53(byte)=10103125bytes message length with headers
Efficiency=9150000/10103125 =90.5 %

b. Discussion

In comparing of the proposed FLC for cell multiplexing and other control approaches using fuzzy logic as shown in literature survey, it has been found that there are many differences between previous works and the present work, in that processing method, the selection of computational parameters, decision mechanisms and aim of research. In spite of this difference, a comparing with study [13] has been done which is the nearest one to present work, that is set Fuzzy Explicit Rate Marking (FERM) traffic flow control algorithm for a class of best effort service, the flow rate is calculated by the fuzzy congestion control module with monitoring *the average (ABR) queue length and its rate of change*.

The main difference between this study and the present work, ***is that the present work uses a different parameters which are called (message length and No. of inputs)*** and the present work requires less computing complexity. And in calculation of Bit Rate the scheme monitors both variables (***message length and No. of inputs***), these parameters provides some form of prediction for future (Bit Rate) control action. The ***maximum throughput*** under FLC parameters (***with message length and No. of inputs)*** is (562.7Mbit/s) for text message, (568Mbit/s) for image message, (563.4Mbit/s) for the video message and (563.4Mbit/s) for audio message. This means that, the present controller for cell multiplexing has a very high speed responding to sudden change in (***No. of inputs and message length)***, while in previous study [13], the maximum ***throughput*** under (FERM) control is 300Mb/s, and the performance does not change critically with changes in reference value, but the controller responds readily to changes requested from higher levels.

The results show, that the time delay is very limited and the throughput performance is high in present work, thus it is capable of transporting different kinds of services message (text, image, audio and video) at high speed and the present work can be a highly effective design.

8:Conclusions

The following conclusion can be derived from the simulation and calculations of results obtained:

1. ATM networking using fuzzy system with multiplexing is based on computer internetworking technology designed to carry video, audio and data simultaneously. ATM technology provides a different level of service necessary to run each of these bandwidth-intensive applications.
2. Increasing of the inputs means that cell queuing will increasing so the (FLC) will achieve size of packet to be large then the flow bit-rate of cell will decrease and when the number of inputs decreases that will let the packet size to be small to achieve a high flow bit-rate. The cell multiplexing ATM network here gives high efficiency.
3. The bit-rate of cell flow depends on the length of the message and the number of inputs (users).
4. The fuzzy system in ATM switch for cell multiplexing

has a very high speed responding to sudden changes in inputs and message length which cause congestion in queue of cells.

9:Reference

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Table (1): Traffic parameters.

Parameter	Definition	Value
PCR	Peak cell rate	149.76 M bit/sec
MCR	Minimum cell rate	2 M bit/sec
Nfp	Control interval	50 cell service provides

Table (2) Rule base table.

Q N	Too short	Short	Normal	Long	Too long
Small	Slowly fast	Sharply fast	Normal	Normal	Normal
Medium	Sharply fast	Fast	Normal	Slow	Slow
Large	Fast	Normal	Normal	Slow	Sharply slow

Table (3) ABR Traffic source model parameters.

Parameter	Distribution	Mean value
Idle	Geometric	Chosen to adjust network load
Number of generated packs in an active period	Geometric	10
Packet size	Geometric	8 k Bytes
Packet period	Exponential	0.5 msec

Table (4) Change in Transmission Time Delay due to bite rate.

Bit Rate (M bit/s)	**Transmission time delay**				
	One cell (μ sec)	**Text message (m sec)**	**Image message (m sec)**	**Video message (sec)**	**Audio message (sec)**
155.52	**2.726**	**11.58**	**24.19**	**1.7207**	**0.51962**
207.36	**2.044**	**8.68**	**18.14**	**1.2905**	**0.38972**
259.20	**1.635**	**6.95**	**14.51**	**1.o324**	**0.31177**
311.04	**1.363**	**5.79**	**12.09**	**0.8603**	**0.25981**
326.88	**1.168**	**4.96**	**10.36**	**0.7374**	**0.22269**
414.72	**1.022**	**4.34**	**9.07**	**0.6452**	**0.22269**
466.56	**0.908**	**3.86**	**8.06**	**0.5735**	**0.19486**
518.40	**0.817**	**3.47**	**7.25**	**0.5162**	**0.15588**
570.24	**0.743**	**3.16**	**6.59**	**0.4693**	**0.14154**
622.08	**0.681**	**2.89**	**6.04**	**0.4302**	**0.12990**

Table (5) Change in Throughput due to Transmission Time Delay.

Text message		Image message		Video message		Audio message	
Transmission time delay (m sec)	Throughput (M bit/s)	Transmission time delay (m sec)	Throughput (M bit/s)	Transmission time delay (m sec)	Throughput (M bit/s)	Transmission time delay (m sec)	Throughput (M bit/s)
11.58	140.6897	24.19	140.8264	1.72073	140.8704	0.51962	140.8700
8.68	187.5862	18.14	188.2873	1.29055	187.8268	0.38972	187.8267
6.95	236.5217	14.51	235.0345	1.03244	234.7836	0.31177	234.7833
5.579	281.3793	12.09	281.6529	0.86030	281.7425	0.25981	281.7400
4.96	326.4000	10.36	327.6923	0.73745	328.7002	0.22269	328.6967
4.34	379.5349	9.07	374.5055	0.64527	375.6162	0.19486	375.6534
3.86	418.4615	8.06	420.7207	0.57357	422.6162	0.17320	422.6101
3.47	466.2857	7.25	466.8493	0.51622	469.5672	0.15588	469.5667
3.16	510.0000	6.59	516.3636	0.46937	516.4369	0.14174	516.4329
2.89	562.7586	6.04	568.000	0.43018	563.4850	0.12990	563.4801

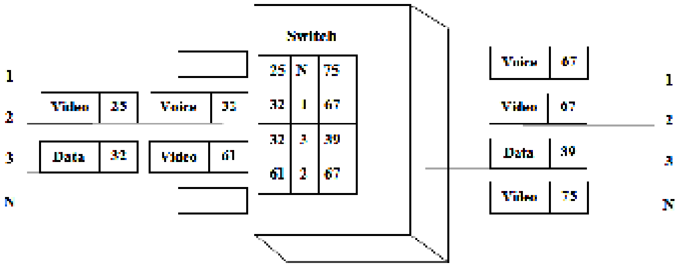


Figure (1) Simulation VCC and VCI are with routing table.

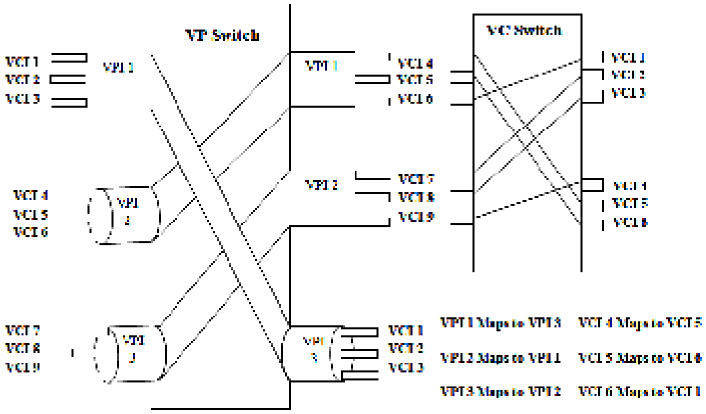


Figure (2) Representation of VP and VC Switching Hierarchy

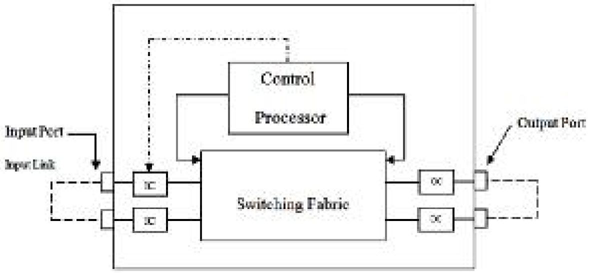


Figure (3) ATM Switching Architecture.

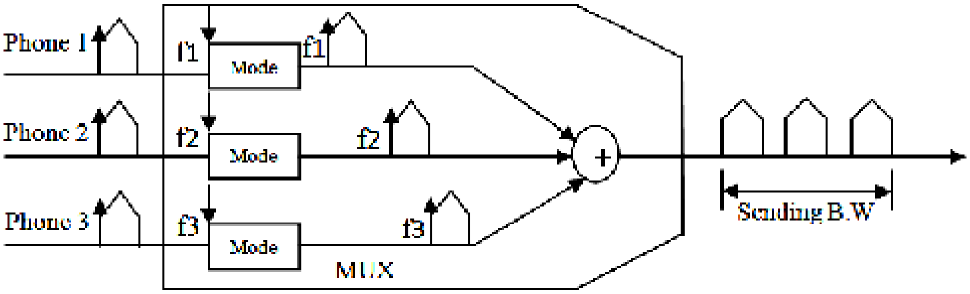


Figure (4) FDM Multiplexing Process in Frequency Domain.

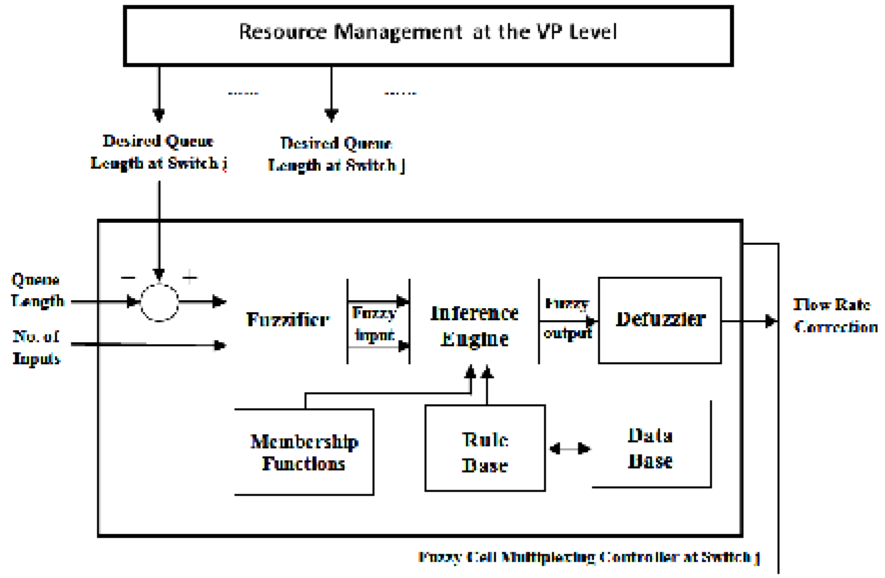


Figure (5) Relationship with the Integrated ATM.): Block Diagram of Fuzzy Cell

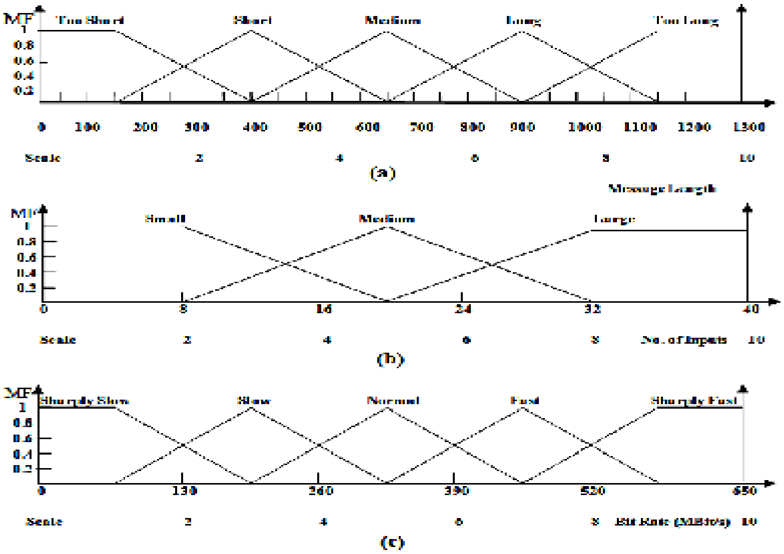


Figure (6) Memberships of Input and Output Variables.

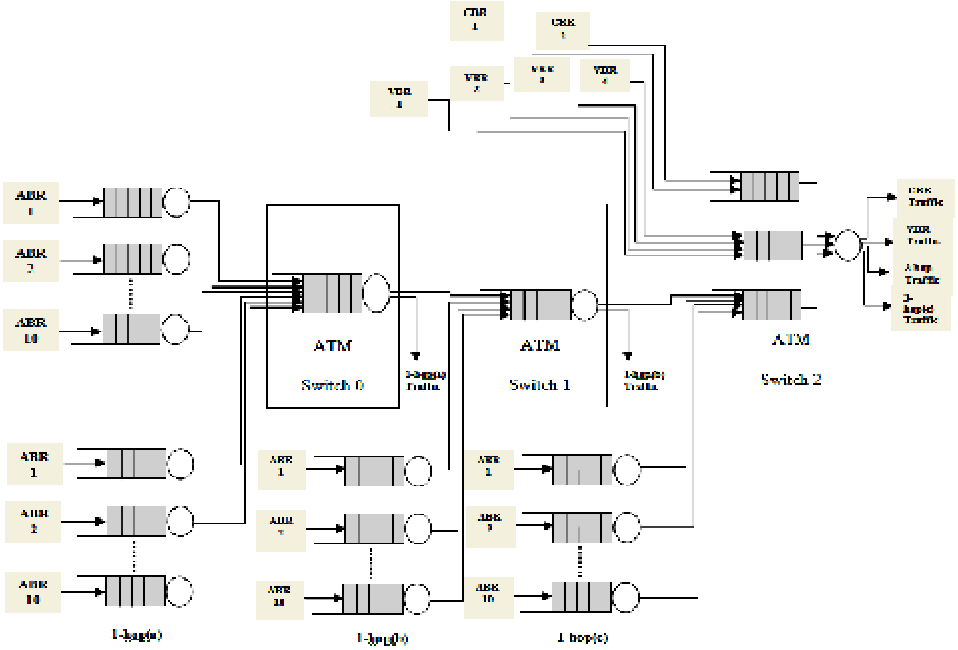
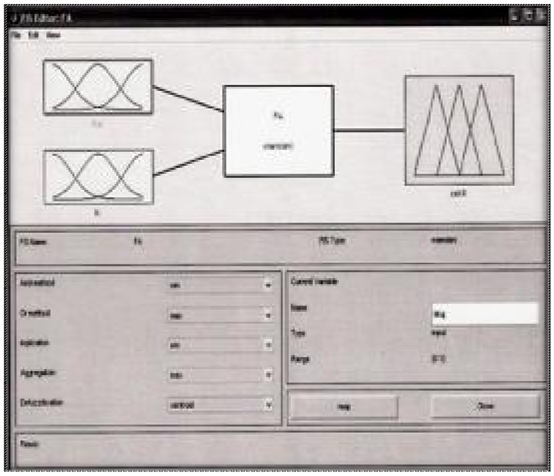
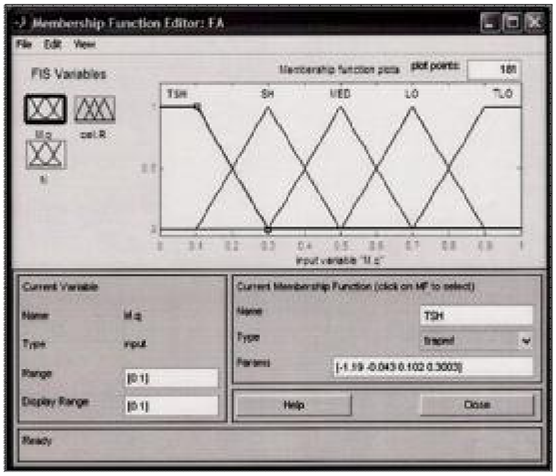


Figure (7) Cell Multiplexing of ATM Network with QoS Categories





Current Variable

Name M.q

Type input

Range [0 1]

Display Range [0 1]

Current Membership Function (click on MF to select)

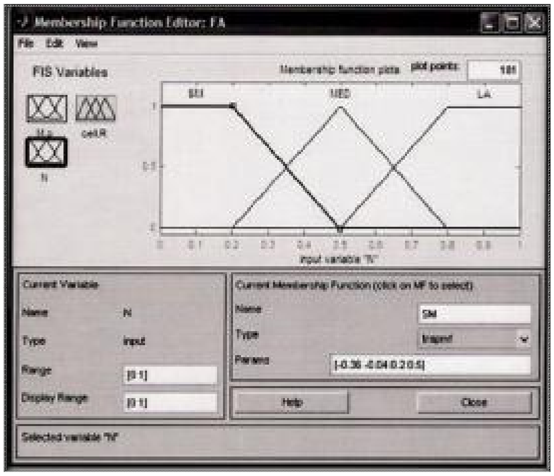
Name TSH

Type trapmf

Params [-1.59 -0.043 0.102 0.3003]

Figure (8) Simulation of FLC for cell multiplexing

Figure (9) Input variable (message length) membership function..

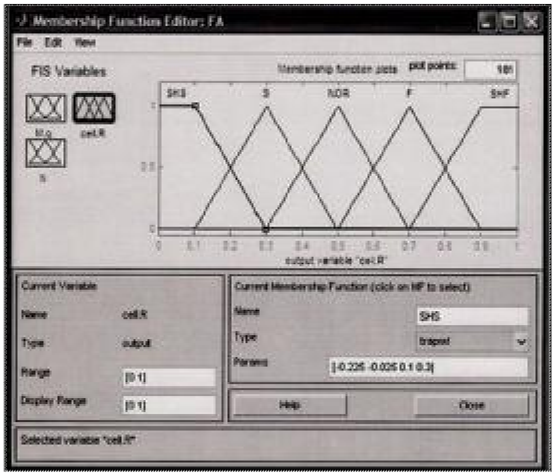


Current Variable
Name N
Type input
Range [0 1]
Display Range [0 1]

Current Membership Function (click on MF to select)
Name SM
Type trapmf
Params [-0.36 -0.04 0.2 0.5]

Selected variable "N"

Figure (10) Input variable (No. of inputs) membership function .



Current Variable
Name cell.R
Type output
Range [0 1]
Display Range [0 1]

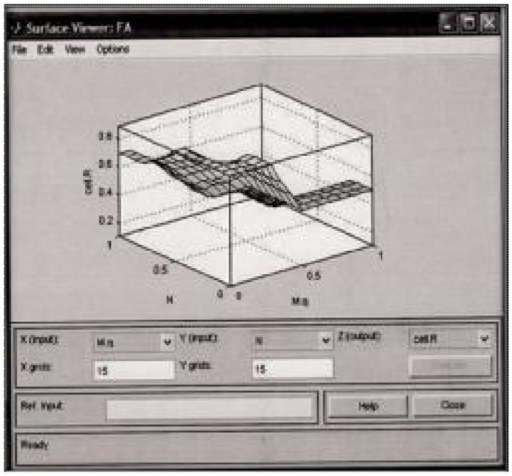
Current Membership Function (click on MF to select)
Name SHS
Type trapmf
Params [-0.225 -0.025 0.1 0.3]

Selected variable "cell.R"

Figure (11) Output variable (call rate) membership function.

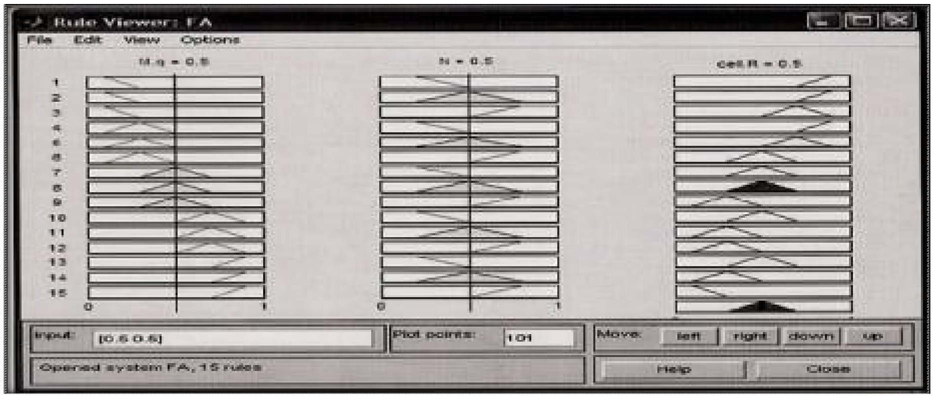
1. If (M.q is TSH) and (N is SM) then (cell.R is SHF) (1)
2. If (M.q is TSH) and (N is MED) then (cell.R is SHF) (1)
3. If (M.q is TSH) and (N is LA) then (cell.R is F) (1)
4. If (M.q is SH) and (N is SM) then (cell.R is SHF) (1)
5. If (M.q is SH) and (N is MED) then (cell.R is F) (1)
6. If (M.q is SH) and (N is LA) then (cell.R is NOR) (1)
7. If (M.q is MED) and (N is SM) then (cell.R is NOR) (1)
8. If (M.q is MED) and (N is MED) then (cell.R is NOR) (1)
9. If (M.q is MED) and (N is LA) then (cell.R is S) (1)
10. If (M.q is LO) and (N is SM) then (cell.R is NOR) (1)
11. If (M.q is LO) and (N is MED) then (cell.R is S) (1)
12. If (M.q is LO) and (N is LA) then (cell.R is S) (1)
13. If (M.q is TLO) and (N is SM) then (cell.R is NOR) (1)
14. If (M.q is TLO) and (N is MED) then (cell.R is S) (1)
15. If (M.q is TLO) and (N is LA) then (cell.R is SHS) (1)

Figure (12): Rules base editor.



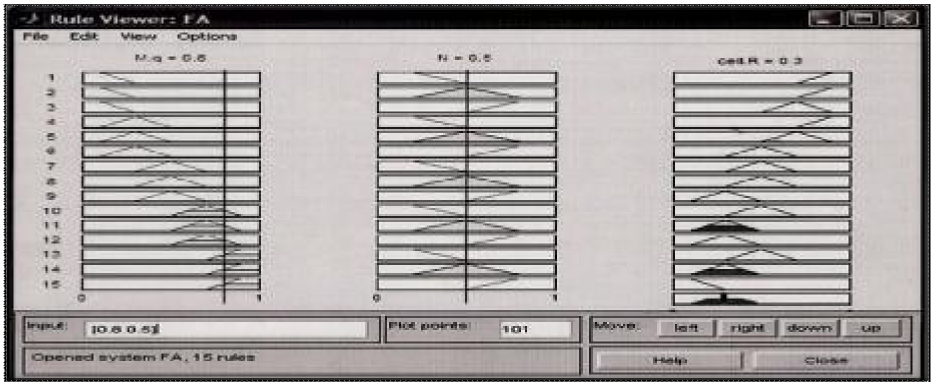
X (input): M.q
Y (input): N
Z (output): cell.R
X grids: 15
Y grids: 15

Figure. (13): Control surface of the fuzzy multiplexing control.



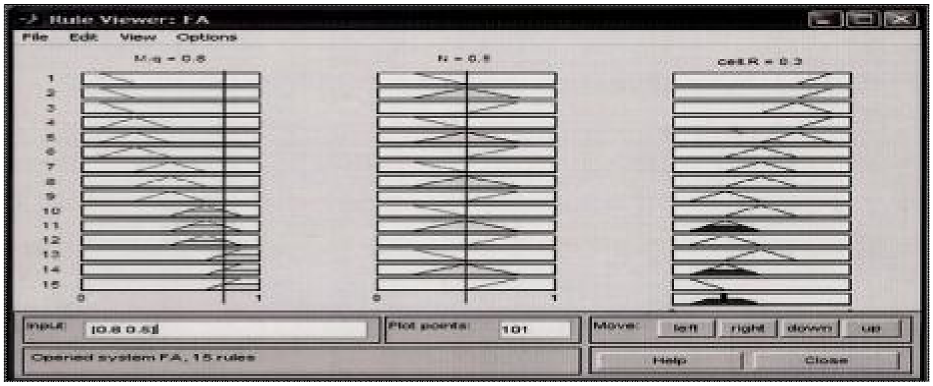
Input: [0.5 0.5]
Plot points: 101
Opened system FA, 15 rules

Figure (14) Rule viewer for M.q=0.5, N=0.5 and control action (cell rate)=0.5 (cell/s).



Input: [0.8 0.5]
Plot points: 101
Opened system FA, 15 rules

Figure (15) Rule viewer for M.q=0.2, N=0.5 and control action (cell rate)=0.777 (cell/s).



Input: [0.8 0.5]
Plot points: 101
Opened system FA, 15 rules

Figure (16) Rule viewer for M.q=0.8, N=0.5 and control action (cell rate)=0.3 (cell/s).

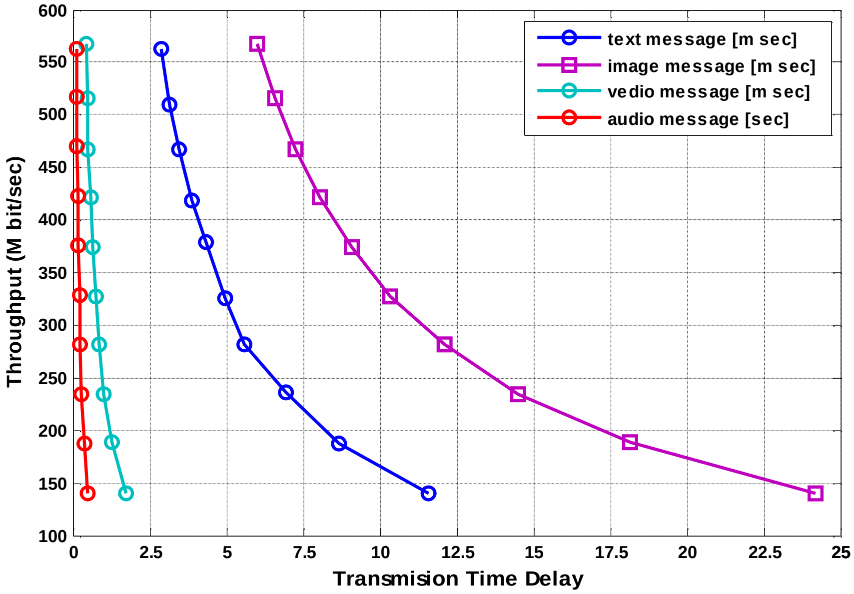


Figure (17) Change in Transmission Time Delay due to changes in bite rate for one cell, text, image, video, audio message.

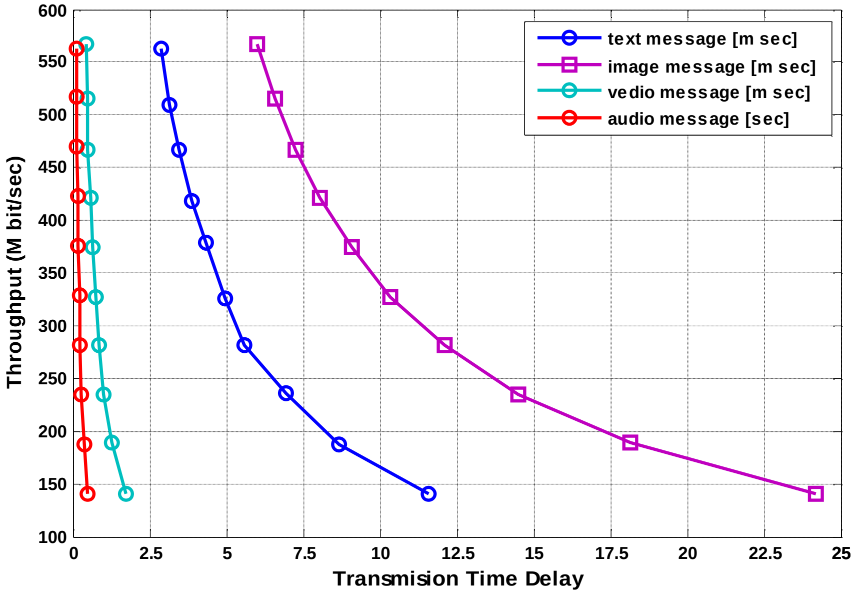


Figure (18) Change in Throughput due to Transmission Time Delay for one cell, text, image, video, audio message.