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A Survey on best three Mathematical Models for the issues in Network Layers

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Abstract

A study on various mathematical models for networks have been done along with the concepts of wireless network, optical communication, radio communication, acoustic communication and issues in networks are identified. The best three mathematical models stochastic network calculus, deterministic network calculus and wireless network calculus are taken and the analysis was made. The important 28 parameters in networks are identified and the best three models are analyzed with all these parameters are addressed. The other existing models are Queuing theory, queuing network theory, Markov fluid model, Markov poisson model and sensor network calculus. The main significance of the work is to identify whether model is available for the identified parameters.

Keywords: *Deterministic Network Calculus, Markov Poissson Model, Stochastic Network Calculus and Queuing Theory*

1. Introduction

Wireless Network

Figure 1. Wireless Network

Wireless Network is a type of network in which the sender and receiver will be communicating with each other through waves without any physical cable connection. The main advantage of this wireless network is to reduce the flexibility, migration, convenience, increased efficiency, no installation problem, easy setup and cost saving. Wireless network transfer the data using packet switching which is connectionless. There are four different types of wireless networks they are Wireless Local Area Network(WLAN), Wireless Wide Area Network(WWAN), Wireless Metropolitan Area Network(WMAN) and Wireless Personal Area Network(WPAN). Examples of wireless network are satellite communication, television remote, Bluetooth, mobile phone communication and wave communications. The major disadvantage of wireless network is speed, based on the location file transfer speed will be slower.

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Optical Communication

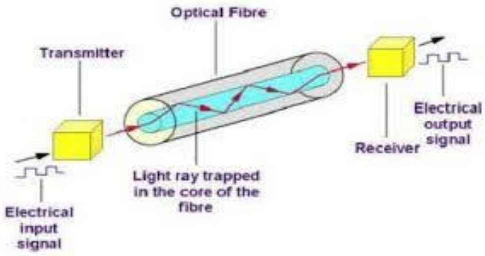

Figure 2. Optical Communication

Optical Communication is a type of passing information between sender and receiver through light using the small photon particles with fiber optic cables. Total internal reflection is the principle used behind this communication with negligible loss of energy. The three major components used are light signal transmitter, the optical fiber, and the photo detecting receiver. The major advantage of optical communication is bandwidth will be high for fiber optic, amount of information transmitted will be more and power loss will be less. There are three different types of fiber optic cable they are single mode, multi mode and plastic fiber cable. The major disadvantage of the optical communication are they are expensive to install and cannot be curved it will break if it is bend too much.

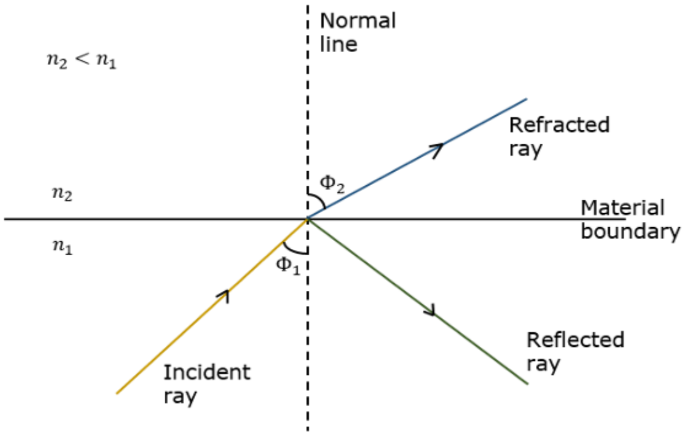

Figure 3. Principle of optical communication

Radio Communication

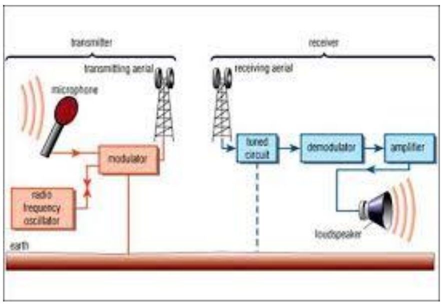

Figure 4. Radio communication

Radio communication is a type of communication which transfers data between sender and receiver through radio waves. The transmitter and receiver antennae make the flow of information, the transmitter antennae produces the radio waves by pulling the electrons up and down and passes to the receiver antennae. Analog radio is of two types Amplitude Modulation and Frequency Modulation. The major advantages of using radio communication is it is faster, more efficient, more secure, provides real time information even across the borders and can connect more members across various sites. The major disadvantages of radio communication

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are it provides only audio, more affected by weather conditions and only fewer frequencies are available.

Acoustic Communication

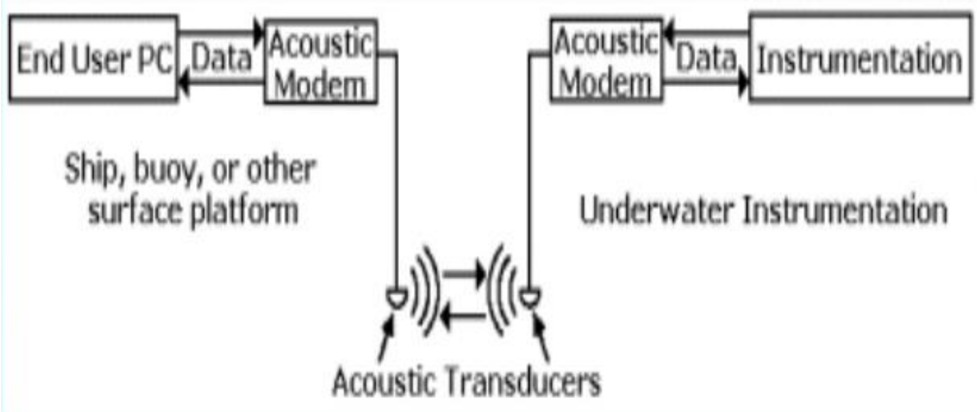

Figure 5. Acoustic Communication

Acoustic communication is a type of communication which will be transmitted through the compressed waves. It is generally produced using the acoustic signals and which will be created by physical object vibrations or an animal which resides in underwater. There are two basic types one is one way communication and the other is two way communications. The components used in acoustic communication are User PC, Acoustic modem and transducers with required instruments. The major advantages of predict the natural disasters, rescue missions, health sector, modern inventions, marine biology and oceanology. The major disadvantage of acoustic communication is long propagation delay and high error probability.

Issues in networks regarding backlog, QoS, Delay and Jitter

Layer	**Fundamental Issues**			
	Network Layer End-to-End Quality of Service			
	Single Hop		Multi-Hop	
Network Layer	Effect of Mapping between NL packets and DL Frames on arrival at DL	Effect of Mapping between NL Packets and DL Frames on service at NL	No interference between neighbor hops	Having interference between neighboring nodes
MAC Layer	Data Link Layer QoS			
	Single sender-receiver pair	Contention-based MAC	FIFO downlink Scheduling	MAX-SNR Scheduling
	Link Layer Service Models			
	Markov Channel Models	Error Probability	Shannon Capacity/ Outrage Capacity	Effective Capacity/ Cumulative Capacity
Communication	Modulation	Retransmission	SISO/MIMO	Cognitive Radio
	Source Coding Channel Coding	Receiver	Diversity	Network Coding
Propagation	Physical Layer Channel Models			
	Rayleigh Fading	**Rician Fading**	**Nakagami Fading**	**Weibull Fading**
	AWGN	Antennas	**Gilbert Fading**	Loss

Figure 6. Issues in Networks

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The five major area under which the issues occur for networks and communication between the networks are Performance degradation, Host identification, Security issues, Configuration conflicts and Network performance issues. The two major types of networks are packet switched networks and circuit switched network. QoS is a technology which is considered in networks to avoid the packet loss, improve delay and latency, provide high efficiency, sets priority for various data in the network to avoid traffic in communication, considers four common methods to share the resources in effective manner and the characteristics are given by reliability, delay, jitter and bandwidth.

Reliability issues in networks will be caused when the system is rebooted or turned on and off often. Since the communication between networks this factor causes impact on an issue in network. Delay is a factor which occurs in network due to the reasons like latency issues, processing, congestion, queuing, traffic and transmission.

There are two different types of delay in networks they are transmission delay and propagation delay. Transmission delay is the time to transmit all the data from sender to receiver. Propagation delay is the time taken to transmit one bit from one router to the other. Delay is the main factor to reduce the throughput of the network. Jitter is an issue in network which occurs due to congestion mainly in audio and video conferencing. The irregular fluctuations in data transfer are acceptable jitters in networks. Jitter can be minimized to some extend by the continuous and fixed Ethernet usage instead of WiFi, when large files are transmitted in the network and number of nodes connected to the same channel can be limited. Packet loss occurs maximum due to the jitter. Bandwidth refers to the number of data transferred from the internet. The bandwidth issues affect the network due to large file download and transfer between computers. By reducing the network load bandwidth can be increased in network.

2. Mathematical model for network

Queuing Theory

Queuing theory is a part of operational research which deals with the study of queues. It often deals with queue length, waiting time, arrival time, response time and efficiency. Now a days queue concepts are available in the entire place as a real time applications like ration shop, banking etc.., Types of queues available are First In First Out, Last In First Out, Priority, Shortest Job First and Processor Sharing. Types of servers used for the queuing theory are Single server, Parallel servers, Tandem queue, Balking, Reneging and Jockeying. The standard symbols used here are λ: the mean arrival rate, μ: the mean service rate and n: the number of people in the system.

Applications

Traffic in vehicles
Patients in hospitals
Banks
Jobs on a machine
Programs in computer

Advantages

The queues used in queuing theory have infinite length, access can be made fast and flexible, data traffic can be reduced, identification of data is easy, maintenance is easy and simple and provides multiple data types to be stored in the same location.

Disadvantages

The two main drawbacks are the waiting space provided in queuing theory is very limited and if a process arrive when the queue line is lengthy then the time taken to process it will be more even though it is important process.

Queuing Network Theory

Queuing network theory consists of computers as a network of queues. The analysis can be done by evaluation. Networks of queue consist of the combination of service nodes, system resource and packets. There are three types of states in the queuing network theory they are transient state, steady state and explosive states. There are three networks they are open queuing network, closed queuing network and mixed queuing network. In the open network new jobs arrives from the

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outside and get serviced and leave the network. In closed network no new job can enter inside the queue only the available jobs will be serviced inside the system. In the mixed network there will be two types of classes one will perform like the open network and the other will perform like the closed network.

Applications

Traffic Tolls

Railway management Systems

Hospitals

Banking Systems

Advantages

For real time application this model provides good accuracy and efficiency.

System can be modeled with low cost with very high efficiency.

Disadvantages

The waiting space provided in queuing theory is very limited.

If a process arrive when the queue line is lengthy then the time taken to process it will be more even though it is important process.

Markov Fluid Model

Markov Fluid model is a type of mathematical model which is similar to the tank in home. The main components in this model are tank, pipe and pumps. The fluid will be filled in the tank and it will be distributed to various pipes by the pump. The capacity of the tank will be infinite. The fluid arrival and leakage speed of the fluid will be made by the operator. The operator is known as the background process which will be always continuous and the fluid buffer can hold only the non negative values. The model can be equated,

$$\frac{\mathrm{d}X(t)}{\mathrm{d}t} = \begin{cases} r_i & \text{if } X(t) > 0 \\ \max(r_i, 0) & \text{if } X(t) = 0. \end{cases}$$

The average fluid level can be given as,

$$\frac{(\lambda-\mu)\beta}{(\mu(\alpha+\beta)-\beta\lambda)(\alpha+\beta)}(\mu, \lambda-\mu).$$

The busy period can be given using Laplace–Stieltjes transform,

$$W^*(s) = \frac{\beta\lambda + s\lambda - \beta\mu + \alpha\mu - \sqrt{4\beta\alpha\mu(\mu-\lambda) + (s\lambda + \beta(\lambda-\mu) + \alpha\mu)^2}}{2\beta(\lambda-\mu)}$$

Hence busy period will be,

$$\mathbb{E}(W) = \frac{\lambda}{\alpha\mu + \beta(\lambda-\mu)}.$$

There are three different types of model for Markov chain process they are homogeneous, heterogeneous and semi Markov model.

Application

Data mining and classification

Multiple alignment

Structural analysis

Pattern discovery

Gene prediction

Modeling protein domain

Advantages

Strong with the usage of statistical functions.

Even the sequence of raw data can be used to develop the efficient learning algorithm directly.

Allow easy acess with both insertion and deletion works.

Easy to combine with libraries.

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Disadvantages

Constructing and validating Markov model is difficult.

Applicable only for very small model if the model is big then it will have more error prone.

Debugging the Markov model is comparatively very difficult.

Markov Poisson Model

Markov Poisson Model is used in the oldest traffic control management. The main characteristics of this model are it is independent and exponentially distributive. It is used for various frameworks effectively. The Poisson process can be decided by measuring the inter arrival time in the networks. The main technique to identify the Poisson process is to use the histogram. The main application of Markov poisson model is in old telephony networks and web information transfer.

Advantages

Time dependent Poisson process can be applied.

Even for random batches of process arrival can be implemented using the Compound Poisson model.

Disadvantages

The inability to maintain the traffic burstiness the important disadvantage of Poisson process model.

Effective Bandwidth

Bandwidth is known as the maximum amount of data transfer. Effective bandwidth is defined as the difference between start and end frequencies of the particle is equal to half of its velocity and always it will be denoted as 3dB bandwidth. Consider R_B as the number of bytes read per kernel W_B as the number of bytes written per kernel and t be the elapsed time then the effective bandwidth can be calculated by the formula,

$$\boxed{\text{BW Effective}=((R_B+W_B)/10^9)/t}$$

Effective bandwidth can be calculated using the two methods one by analytical expressions and another one by the usage of effective traffic data determination. Effective bandwidth will allow the user to improve the upload and download the large amount of data transfers. The major application of the effective bandwidth is in the website for data transfer.

Advantages

Faster data transfer speed

Increased data transfer capability

Simultaneously allow more users at a time

Decrease the number of crashes, bounces or busy signals

Multiple concurrent sessions can be supported

Streaming of videos can be done faster

Disadvantages

Affects the rate of data transfer

Occurrence of internal and external noise will affect the network data transfer

Sensor Network Calculus

Sensor Network Calculus will provide the worst case provision for the performances of the model designed.

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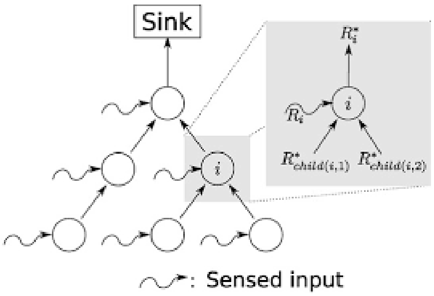

Figure 7. Model of Sensor Network Calculus

In the sensor network calculus there will be only one base station and surrounded by various sensor nodes. Data communication will happen in between the nodes through the single base station, it forms the structure in the sink tree model. Each sensor connected in the tree will senses its environment and sends to the sink and any traffic in the data has to be managed by itself. Sensor network calculus customizes and extends various features to attain the benefits in the wireless networks an example is in-network processing.

Application

Home and health monitoring
Animal tracking
Agriculture
Healthcare
Traffic
Military
Flood

Advantages

Effective in Hostile Environments
Offer an Easily Scaled Solutions
Enable Long-distance Data Collection and Transmission
Can Anticipate in Natural Disasters
Can Protect Hardware and Data Assets

Disadvantage

Battery life and transmitting capabilities is less
Inexpensive to purchase and operate

Deterministic Network calculus

Deterministic Network calculus is a type of mathematical model which can be implemented in the worst cases of data flow in end to end delay. The two main classifications on accuracy of DNC are classical algebraic analysis and optimization based analysis. Most of the model in existence uses the optimization based analysis methods. Both models shares the same network models but uses different tools to derive the delay with accuracy. Already DNC work wit end to end delay systems but it has been a hard problem to generate the accurate results. The common network calculus models are data arrivals and forwarding services, network model for both arbitrary multiplexing and feed forward property. The main operations of (min,+) algebraic DNC model are aggregation, convolution and deconvolution.

Application

Packet Scheduling
Formation of network with best accuracy and cost
GPS implementation
Traffic modeling

Advantages

Algebraic DNC can be considerably improved the accuracy and computational cost of the system
Maximizes the aggregation of cross-flows
Minimizes the segregation
Optimization DNC can be used to identify the end to end delay accurately

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Disadvantages
Formulation is not accurate for the various network sizes
Optimization based DNC will not provide fast heuristics for bounded delays

Stochastic Network Calculus
Stochastic network calculus is a combination of effective bandwidth and deterministic network calculus. The main goal of this model is to design and control the queuing networks and it is also used to deal with non-Poisson arrival systems. When there are more number of jobs arriving in same time in non-poisson distribution manner then this method can be used faster. The main operations performed in SNC are multiplexing, subtraction, convolution and deconvolution . The difference in various stochastic network calculi can be identified by two methods they are Moment Generation Function and Tailbounds cut off unwanted outcomes. In tailbound method the two operations available are envelop function and error function. The only tool that is used for SNC is Stochastic Network Calculator. This method can be accessed directly or by creating classes as interface between optimizer, analysis and network.
Application
Queuing systems for internet
Communication surveys
Performance evaluation in internet
Automatic telephone exchange
Quantitative finance
Modeling and analyzing the fading channels
Advantages
Implemented for hard problems since it is combination of effective bandwidth and deterministic network calculus.
When there are more number of jobs arriving in same time in non-Poisson distribution manner then this method can be used faster.
Disadvantages
Difficult to analyze the loss analysis
Packet loss
Feedback control
Wireless channels

Wireless Network Calculus
Wireless network calculus is a type of mathematical model in which wireless channels will have the features of stochastic network calculus. The channels will work in two states one is good and the other is bad. When it functions in good state then more amount of data will be transmitted between the sender and receiver. When it function in bad state then it undergoes various impairments. Wifi, Bluetooth and Zigbee are the scenario in which the wireless network calculus works effectively. For emergency response monitoring system wireless network calculus can be preferred for more accuracy and efficiency.

Application
WiFi
Bluetooth
Disaster area monitoring
Healthcare monitoring
Advantages
Increased mobility and collaboration
Improved responsiveness
Better access to information
Easier network expansion
Enhanced guest access
Disadvantages
Wireless propagation channel along with antennas and cognitive radio is difficult

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Wireless communication link for modulation and receiver
Implementation of multiple access control

Finally the best models are Stochastic Network Calculus, Deterministic Network Calculus and Wireless Network Calculus and these three models are currently implemented for real time applications with high accuracy and efficiency.

3.Analysis of Mathematical model for SNC, DNC and WNC

Table 1. Analysis of Stochastic Network Calculus for network parameters

S.No	Parameters	Stochastic Network Calculus in Wireless Networks	Stochastic Network Calculus in Wireless Radio Communication	Stochastic Network Calculus in Wireless Optical Communication	Stochastic Network Calculus in Wireless Acoustic Communication
1	Effect of mapping between NL Packets and DL frames on arrival at DL	Yes	Yes	No	No
2	Effect of mapping between NL Packets and DL frames on service at NL	Yes	Yes	No	No
3	No interference between neighbour hops	Yes	Yes	Yes	Yes
4	Having interference between neighbour hops	Yes	Yes	Yes	Yes
5	Single Sender - Receiver pair	Yes	Yes	Yes	Yes
S.No	**Parameters**	**Stochastic Network Calculus in Wireless Networks**	**Stochastic Network Calculus in Wireless Radio Communication**	**Stochastic Network Calculus in Wireless Optical Communication**	**Stochastic Network Calculus in Wireless Acoustic Communication**
6	Content based MAC	Yes	Yes	Yes	Yes
7	FIFO downlink Scheduling	Yes	Yes	Yes	Yes
8	MAX SNR Scheduling	Yes	Yes	Yes	Yes
9	Markov channel models	Yes	Yes	Yes	Yes
10	Error probability	Yes	Yes	Yes	Yes
11	Shannon capacity and outrage capacity	Yes	Yes	No	Yes
12	Effective capacity and Cumulative	Yes	Yes	Yes	Yes

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	capacity				
13	Modulation	Yes	Yes	Yes	Yes
14	Retransmission	Yes	Yes	Yes	Yes
15	SISO / MIMO	Yes	Yes	Yes	Yes
16	Cognitive Radio	Yes	Yes	Yes	Yes
17	Source coding Channel coding	Yes	Yes	Yes	Yes
18	Reciever	Yes	Yes	Yes	Yes
19	Diversity	Yes	Yes	Yes	Yes
20	Network coding	Yes	Yes	Yes	Yes
21	Rayleign fading	Yes	Yes	Yes	Yes
22	Rician fading	Yes	Yes	Yes	Yes
S.No	**Parameters**	**Stochastic Network Calculus in Wireless Networks**	**Stochastic Network Calculus in Wireless Radio Communication**	**Stochastic Network Calculus in Wireless Optical Communication**	**Stochastic Network Calculus in Wireless Acoustic Communication**
23	Nakagami fading	Yes	Yes	Yes	Yes
24	Weibull fading	Yes	Yes	Yes	Yes
25	Additive White Guassian Noise	Yes	Yes	Yes	Yes
26	Antennas	Yes	Yes	Yes	Yes
27	Gilbert Fading	Yes	Yes	Yes	Yes
28	Noise	Yes	Yes	Yes	Yes

The above table shows the major 28 issues in networks and whether any model has been implemented using Stochastic Network Calculus in four major types of communication like wireless networks, wireless radio communication, wireless optical communication and wireless acoustic communication.

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Table 2. Analysis of Deterministic Network Calculus for network parameters

S.No	Parameters	Deterministic Network Calculus in Wireless Networks	Deterministic Network Calculus in Wireless Radio Communication	Deterministic Network Calculus in Wireless Optical Communication	Deterministic Network Calculus in Wireless Acoustic Communication
1	Effect of mapping between NL Packets and DL frames on arrival at DL	No	No	No	No
2	Effect of mapping between NL Packets and DL frames on service at NL	No	No	No	No
3	No interference between neighbour hops	Yes	Yes	Yes	Yes
S.No	Parameters	Deterministic Network Calculus in Wireless Networks	Deterministic Network Calculus in Wireless Radio Communication	Deterministic Network Calculus in Wireless Optical Communication	Deterministic Network Calculus in Wireless Acoustic Communication
4	Having interference between neighbour hops	Yes	Yes	Yes	Yes
5	Single Sender - Receiver pair	Yes	Yes	Yes	Yes
6	Content based MAC	Yes	Yes	Yes	Yes
7	FIFO downlink Scheduling	Yes	Yes	Yes	Yes
8	MAX SNR Scheduling	No	Yes	Yes	No
9	Markov channel models	Yes	Yes	Yes	Yes
10	Error probability	Yes	Yes	Yes	Yes
11	Shannon capacity and outrage capacity	No	No	No	No
12	Effective capacity and Cumulative capacity	Yes	Yes	Yes	Yes
13	Modulation	Yes	Yes	Yes	Yes
14	Retransmission	Yes	Yes	Yes	Yes

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15	SISO / MIMO	Yes	Yes	Yes	Yes
16	Cognitive Radio	Yes	Yes	Yes	Yes
17	Source coding Channel coding	Yes	Yes	Yes	Yes
18	Reciever	Yes	Yes	Yes	No
19	Diversity	Yes	Yes	Yes	Yes
20	Network coding	Yes	Yes	Yes	Yes
21	Rayleign fading	Yes	Yes	Yes	Yes
22	Rician fading	Yes	Yes	Yes	Yes
23	Nakagami fading	Yes	Yes	Yes	Yes
24	Weibull fading	Yes	Yes	Yes	Yes
25	Additive White Guassian Noise	Yes	Yes	Yes	Yes
S.No	**Parameters**	**Deterministic Network Calculus in Wireless Networks**	**Deterministic Network Calculus in Wireless Radio Communication**	**Deterministic Network Calculus in Wireless Optical Communication**	**Deterministic Network Calculus in Wireless Acoustic Communication**
26	Antennas	No	Yes	Yes	Yes
27	Gilbert Fading	Yes	Yes	Yes	Yes
28	Noise	Yes	Yes	Yes	Yes

The above table shows the major 28 issues in networks and whether any model has been implemented using Deterministic Network Calculus in four major types of communication like wireless networks, wireless radio communication, wireless optical communication and wireless acoustic communication.

Table 3. Analysis of Wireless Network Calculus for network parameters

S.No	**Parameters**	**Wireless Network Calculus in Wireless Networks**	**Wireless Network Calculus in Wireless Radio Communication**	**Wireless Network Calculus in Wireless Optical Communication**	**Wireless Network Calculus in Wireless Acoustic Communication**
1	Effect of mapping between NL Packets and DL frames on arrival at DL	No	No	No	No
2	Effect of mapping between NL Packets and DL frames on service at NL	Yes	No	No	No
3	No interference between neighbour hops	Yes	No	Yes	No
4	Having interference between neighbour hops	Yes	No	No	No

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5	Single Sender - Receiver pair	Yes	Yes	No	No
6	Content based MAC	Yes	No	Yes	No
7	FIFO downlink Scheduling	Yes	No	No	Yes
8	MAX SNR Scheduling	Yes	No	No	No
9	Markov channel models	Yes	No	No	No
10	Error probability	Yes	Yes	No	No
11	Shannon capacity and outrage capacity	No	No	No	No
S.No	**Parameters**	**Wireless Network Calculus in Wireless Networks**	**Wireless Network Calculus in Wireless Radio Communication**	**Wireless Network Calculus in Wireless Optical Communication**	**Wireless Network Calculus in Wireless Acoustic Communication**
12	Effective capacity and Cumulative capacity	Yes	Yes	No	Yes
13	Modulation	Yes	Yes	No	Yes
14	Retransmission	Yes	Yes	No	No
15	SISO / MIMO	Yes	No	Yes	No
16	Cognitive Radio	Yes	No	Yes	Yes
17	Source coding Channel coding	Yes	No	No	No
18	Reciever	Yes	No	No	No
19	Diversity	Yes	No	No	No
20	Network coding	No	Yes	No	No
21	Rayleign fading	Yes	No	No	No
22	Rician fading	Yes	No	No	No
23	Nakagami fading	No	No	No	Yes
24	Weibull fading	Yes	No	No	No
25	Additive White Guassian Noise	No	No	No	No
26	Antennas	Yes	No	No	Yes
27	Gilbert Fading	No	No	No	No
28	Noise	Yes	Yes	Yes	Yes

The above table shows the major 28 issues in networks and whether any model has been implemented using Wireless Network Calculus in four major types of communication like wireless networks, wireless radio communication, wireless optical communication and wireless acoustic communication

Conclusion

In summary of the research article the best three mathematical models among the others has been identified based on the current usage. The introduction to the various network communication and issues are presented. Major parameters in the network layers have been identified and analysis for the best mathematical models available features has been tabulated. In future the area in which solution has not been identified can be modeled.

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