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Propagation Models for Next Generation Networks in NS-3:A Survey

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Abstract:- Simulations of mobile radio systems require propagation models for determining the channel characteristics for a given arbitrary scenario. Propagation path loss models can be used to predict wireless channel characteristics like received signal strength, multipath effects, and interference. These predictions are an important aspect of simulation of wireless networks and aid in the high-level network planning process. Various models are available for modeling propagation characteristics and they vary in terms of both modeling performance and computational complexity. Propagation path loss models can be used to predict wireless channel characteristics like received signal strength, multipath effects, and interference. This paper includes the discussion on next generation networks and propagation models in NS3.

Keywords:- Simulations, Propagation, Path loss, Performance, NS3.

I. INTRODUCTION

An important aspect of network simulation of wireless systems is the ability to accurately model the wireless channel effects and to evaluate its impact on system performance. Channel modeling is a fundamental task during the modeling of mobile communication systems. Various channel models have been proposed in the past to be used for simulating the mobile communication systems. With advent of LTE (Long Term Evolution), the need to modify the existing channel models has to be surfaced, especially as new frequency bands have been allocated to LTE. The Empirical propagation models have found favour in both research and industrial communities owing to their speed of execution and their limited reliance on detailed knowledge of the terrain. Although the study of empirical propagation models for mobile channels has been exhaustive, their applicability for FWA (Fixed Wireless Access) systems is yet to be properly validated. Among the contenders, the ECC-33 model, the Stanford University Interim (SUI) models and the COST-231 Hata model show the most promise.

In telecommunications and computer networking, a communication channel or channel, refers either to a physical transmission medium such as a wire, or to a logical connection over a multiplexed medium such as a radio channel. A channel is used to convey an information signal, for example a digital bit stream, from one or several *senders* (or transmitters) to one or several *receivers*. A channel has a certain capacity for transmitting information, often measured by its bandwidth in Hz or its data rate in bits per second. A channel can be modelled physically by trying to calculate the physical processes which modify the transmitted signal. For example, in wireless communications the channel can be modelled by calculating the reflection off every object in the environment. A sequence of random numbers might also be added in to simulate external interference and/or electronic noise in the receiver. Generally, three stage modeling process is described or employed to obtain a practical predication model.
(i) The first stage involves the digitization of analogue terrain data to obtain digital terrain databases. These databases maintain information regarding terrain height, land usage data, building shapes and surface characteristics.
(ii) The second stage involves process of defining mathematical approximations for physical propagation mechanisms based on the terrain data information.
(iii) The third stage will involve the creation of both deterministic and empirical solutions based on the approximations for various environments like urban, sub-urban and rural.

The term "model" refers to the process of generating abstract, conceptual, graphical and mathematical models. This term can also be defined as a simulation of the real system that omits all but essential variables of the system.

Growth of Internet and other IP-based networks with their requirements for bandwidth and capacity has driven rapid innovation in telecommunication access and transport networks. Evolution of current PSTN, mobile, wireless and IP-based networks to unified Next Generation Networks providing both Internet and carrier-grade telecommunications networks and services offerings with QoS. “A Next Generation Network (NGN) is a packet-based network able to provide services including Telecommunications Services and able to make use of multiple broadband, QoS-enabled transport technologies and in which service-related functions are independent from underlying transport-related technologies. It offers unrestricted access by users to different service providers. It supports generalized mobility which will allow consistent and ubiquitous provision of services to users." One of the primary goals of NGN is to provide a common, unified, and flexible service architecture that can support multiple types of services over multiple types of transport networks. NGN is the public packet-based network with the following main features: Layered architecture, Open interfaces between the layers and all other networks, Seamless control of multiple transport technologies and Centralized intelligence. NGN is characterized by the following fundamental aspects:

- Packet-based transfer in the core NGN network.
- Support for a wide range of services, applications and mechanisms (including real time/ streaming/ non-real time services and multi-media)
- Independence of service-related functions from underlying transport technologies.
- Separation of control functions among bearer capabilities, call/session, and applications/services.
- Broadband capabilities with required end-to-end QoS.
- Interworking with legacy networks via open interfaces.
- Generalized mobility.
- Unrestricted access by users to different service providers.
- Services convergence between Fixed/Mobile.
- Compliance with all Regulatory requirements, for example concerning emergency communications, security/privacy etc.

Services provided by NGN includes:

- **Voice Telephony** – NGN will likely need to support various existing voice telephony services (e.g., Call Waiting, Call Forwarding, 3-Way Calling, various IN features, various Centrex features and etc.).
- **Data Services** – Allows for the real-time establishment of connectivity between endpoints, along with various value-added features
- **Multimedia Services** – Allows multiple parties to interact using voice, video, and/or data.
- **Virtual Private Networks (VPNs)** – Voice VPNs improve the interlocation networking capabilities of businesses by allowing large, geographically dispersed organizations to combine their existing private networks with portions of the PSTN, thus providing subscribers with uniform dialing capabilities.
- **Public Network Computing (PNC)** – Provides public network-based computing services for businesses and consumers.
- **Unified Messaging** – Supports the delivery of voice mail, email, fax mail, and pages through common interfaces.
- **Information Brokering** – Involves advertising, finding, and providing information to match consumers with providers.
- **E-Commerce** – Allows consumers to purchase goods and services electronically over the network. Home banking and home shopping fall into this category of services. This also includes business-to-business applications etc.

The development of efficient transmission, operation and management technologies and a progressive reduction in the size of the cells requires a greater suitability on the estimations of the system coverage, which is given by propagation losses, in order to obtain "total coverage" with which the operator attempts to assurance the quality of service. The paper discusses the different propagation models.

Figure 1 indicates NGN network architecture:

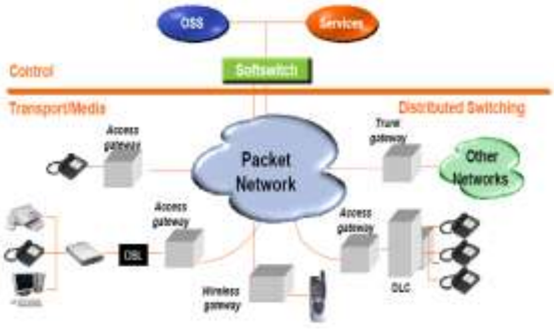

Fig. 1 NGN Network Architecture

II. INTRODUCTION TO NS3

Network Simulation is a powerful tool for analysis and evaluation of wireless networks.NS3 is network simulator software that can be run under ubuntu or linux operating system. Simulator core and model library are entirely written in C++.In NS3, the script configures network topology and simulation values in main function using a set of available libraries.NS3 alignment with real systems like sockets, device driver interfaces. The priority of NS3 is test bed integration.

The C++ functions and keys used in NS3 are:

- C++ functions schedule events to occur at specific simulation time.
- Simulator::Schedule is the default scheduler function in non real time.
- Simulator::run to start the simulation.
- NODE is a computing device that connects to the network.
- CHANNEL is specialized to obtain functionality.
- WIFICHANNEL is used to work with Wifi channels.
- NETDEVICES provide methods for managing connections to NODE and CHANNEL objects.

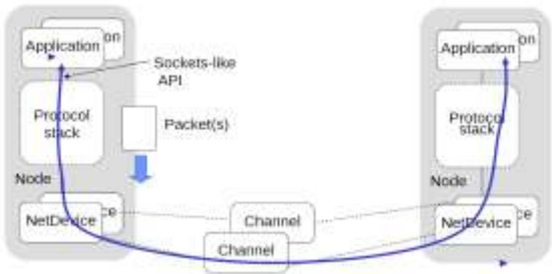

Fig.2 Shows how NS3 applications run in simulation world

NS3 is the basic abstraction for a user program that generates some activity to be simulated.NS3 represent a process on actual system.NS3 application runs on NS3 node to drive simulations in the simulated world. The NS3 application talks to networks stacks through sockets. NS-3 is a research-oriented, discrete-event network simulator and it is an open source licensing and developing model. Propagation models are used extensively in network planning, particularly for conducting feasibility studies and during initial deployment. These models can be classified broadly as Deterministic, Stochastic and Empirical Models. The deterministic models make use of the laws governing electromagnetic wave propagation to determine the received signal power at a particular location. Deterministic models often require a complete 3-D map of the propagation environment. An example of a deterministic model is a ray tracing model. Stochastic models use a stochastic fading process and model the environment by applying a random fading process on top of a path loss model. The random process Accounts for non-deterministic effects caused due to user mobility. These models are generally the least accurate and have low computational complexity for generating predictions. Empirical models are those based on observations and measurements alone. These models are mainly used to predict the path loss, but models that predict rain-fade and multipath.

III. PROPAGATION MODELS

Propagation study provides an estimation of signal characteristics. A propagation model is a set of mathematical expressions, diagrams, and algorithms used to represent the radio characteristics of a given environment. The accuracy of any particular propagation model in any given condition will depend on the suitability among the constraints required by the model and depend on terrain. The radio propagation phenomena to be identified as the most important depend on the environment and differ whether we consider flat terrain covered with grass, or brick houses in a suburban area, or buildings in a modern city centre etc. Propagation models are more efficient when only the most dominant phenomena are taken into account. Which radio propagation phenomena need to be taken into account and in how much detail do they need to be considered will also differ whether we are interested in modeling the average signal strength, or a fading statistic, or the delay spread, or any other characteristics.

For different propagation mechanisms the range dependence of the field strength is given in the following:

- For specular reflection the field is proportional to $(d1+d2)^{-1}$,
- for single diffraction, the field is proportional to $(d1/d2(d1+d2))^{-0.5}$,
- For multiple diffraction and for a source illuminating all edges, the field is proportional to $d^{-1.9}$,
- For volume scattering and rough surface scattering, the field is proportional to $(d1d2)^{-1}$,
- For penetration and absorption, the field is mainly attenuated by a constant,
- For the wave guiding phenomena, the logarithm of the field is proportional to d.

Propagation loss models are used extensively for path loss prediction in large and small cell configurations under both Line-of-Sight (LoS) and Non Line-of-Sight (NLoS) conditions. They are useful in conducting

feasibility studies during initial deployment and aid in high-level network planning. The ns-3 simulation platform has an implementation of 11 different propagation models for predicting path loss behavior.
Many models have been proposed previously to wireless mobile network system. They are as follows:

3.1 FRIIS Propagation Loss Model:

The Friis propagation loss model was first described in "A Note on a Simple Transmission Formula", by "Harald T. Friis".In its simplest form, the Friis transmission equation is as follows. Given two antennas, the ratio of power available at the input of the receiving antenna,P_r , to output power to the transmitting antenna, P_t ,is given by: $\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R}\right)^2$ where G_t and G_r are the antenna gains (with respect to an isotropic radiator) of the transmitting and receiving antennas respectively, λ is the wavelength, and R is the distance between the antennas. The inverse of the factor in parentheses is the so-called free-space path loss. To use the equation as written, the antenna gain may *not* be in units of decibels, and the wavelength and distance units must be the same. If the gain has units of dB, the equation is slightly modified to: $P_r = P_t + G_t + G_r + 20log_{10}\left(\frac{\lambda}{4\pi R}\right)$ (Gain has units of dB, and power has units of dBm or dBW) where P_r : reception power (W) ,P_t : transmission power (W), G_t: transmission gain (unit-less), G_r: reception gain (unit-less), λ :wavelength (m), d : distance (m), L : system loss (unit-less). This model is invalid for small distance values. The current implementation returns the txpower as the repower for any distance smaller than MinDistance.

3.2 Log Distance Model:

A Log distance propagation loss model is a radio propagation model that predicts the path loss a signal encounters inside a building or densely populated areas over distance. A log distance propagation model.This model calculates the reception power with a so-called log-distance propagation model: $L = L_0 + 10n log_{10}\left(\frac{d}{d_0}\right)$ where:n : the path loss distance exponent, d_o : reference distance (m), L_0 : path loss at reference distance (dB), d : distance (m), L : path loss (dB). When the path loss is requested at a distance smaller than the reference distance, the tx power is returned.

3.3 Jakes Propagation Loss Model:

The Jakes propagation loss model implemented here is described and we call path the set of rays that depart from a given transmitter and arrive to a given receiver. For each ray the complex coefficient is compute as follow: $u(t) = u_c(t) + ju_s(t)$, $u_c(t) = \frac{2}{\sqrt{N}}\sum_{n=0}^{M} a_n \cos(\omega_n t + \phi_n)$,

$u_s(t) = \frac{2}{\sqrt{N}}\sum_{n=0}^{M} b_n \cos(\omega_n t + \phi_n)$,

where$a_n = \begin{cases} \sqrt{2}\cos\beta_0 & n = 0 \\ 2\cos\beta_n & n = 1,2,\dots,M \end{cases}$

$b_n = \begin{cases} \sqrt{2}\sin\beta_0 & n = 0 \\ 2\sin\beta_n & n = 1,2,\dots,M \end{cases}$ $\beta_n = \begin{cases} \frac{\pi}{4} & n = 0 \\ \frac{\pi n}{M} & n = 1,2,\dots,M \end{cases}$

$\omega_n = \begin{cases} 2\pi f_d & n = 0 \\ 2\pi f_d \cos\frac{2\pi n}{N} & n = 1,2,\dots,M \end{cases}$.

The parameter f_d is the Doppler frequency and $N=4M+2$ where M is the number of oscillators per ray.The attenuation coefficient of the path is the magnitude of the sum of all the ray coefficients. This attenuation coefficient could be greater than 1 , hence it is divided by $\frac{2N_r}{\sqrt{N}}\sum_{n+0}^{M}\sqrt{a_n^2 + b_n^2}$ where N_r is the number of rays. The initial phases □□ are random and they are chosen according to a given distribution.

3.4 Nakagami Propagation Loss Model:

Nakagami-m fast fading propagation loss model. The Nakagami-m distribution is applied to the power level. The probability density function is defined as:

$$p(x,m,\omega) = \frac{2m^m}{\Gamma(m)\,\omega^m} x^{2m-1} e^{-\frac{m}{\omega}x^2} =$$
$$2x.\,p_{Gamma}\,(x^2, m, \frac{m}{\omega})$$

With *m* the fading depth parameter and the average received power. It is implemented by either a NS3::Gamma Variable or a ns3::ErlangVariable random variable. Like in NS3::Three Log Distance Propagation Loss Model, the m parameter is varied over three distance fields: $\underbrace{0 \cdots\cdots}_{m_0} \underbrace{d_1 \cdots\cdots}_{m_1} \underbrace{d_2 \cdots\cdots \infty}_{m_2}$. For m = 1 the Nakagami-m distribution equals the Rayleigh distribution. Thus this model also implements Rayleigh distribution based fast fading.

Even though these models were developed in order to overcome the loss of data along the path from transmitter to receiver, they were not able to control path loss therefore a new model were proposed.

The models predict the average path loss as a function of various parameters like distance from the transmitter; transmit/receive antenna heights, rooftop/building information and frequency. In this paper, we present the three propagation loss models for ns-3 namely: COST-231 Walfisch Ikegami , SUI channel models and ECC-33 model.

3.5 COSTS-231 Walfisch Ikegami Model:

The COST 231 model is a path-loss model when small distances exist between the MS and BS, and/or the MS has a small height. COST 231 is a model that is widely used for predicting path loss in mobile wireless system is the COST-231 model . It was devised as an extension to the Hata-Okumura model. The COST-231 model is designed to be used in the frequency band from 500 MHz to 2000 MHz It also contains corrections for urban, suburban and rural (flat) environments. Although its frequency range is outside that of the measurements, its simplicity and the availability of correction factors has seen it widely used for path loss prediction at this frequency band. COST 231-Walfisch-Ikegami model is based on considerations of reflection and scattering above and between buildings in urban environments. It considers both line of sight (LOS) and non line of sight (NLOS) situations.The case of line of sight is approximated by a model using free-space approximation up to 20 m and the following beyond: $L_{LOS}=42.6+26log(d/1km)+20log(f/1MHz)$ *for* $d>=20m$.The model for non line of sight takes into account various scattering and diffraction properties of the surrounding buildings: $L_{NLOS}=L_0+max\{0,L_{rts}+L_{msd}\}$ where L_0 represents free space loss, L_{rts} is a correction factor representing diffraction and scatter from rooftop to street, and L_{msd} represents multiscreen diffraction due to urban rows of buildings.

$L_0 = 32.4 + 20\log(d/1km) + 20\log(f/1MHz)$; $L_{rts} = -16.9 - 10\log(w/1m) + 10\log(f/1MHz) + 20\log(\Delta h_M/1m) + L_{ori.}$
w=Average street width

$\Delta h_M = h_{Roof} - h_M$

$$L_{ori=} \begin{cases} -10 + 0.354\phi/1deg & \text{if } 0^\circ \le \phi < 35^\circ \\ 2.5 + 0.0.075(\phi/1deg - 35) & \text{if } 35^\circ \le \phi < 55^\circ \\ 4.0 - 0.114(\phi/1deg - 55) & \text{if } 55^\circ \le \phi < 90^\circ \end{cases}$$

$L_{msd} = L_{bsh} + k_a + k_d \log(d/1km)\ k_f \log(f/1MHz) - 9\log(b/1m)$

B =Average building separation

$$L_{bsh}= \begin{cases} -18\log(1 + \Delta h_B/1m) & \text{for } h_B > h_{Roof} \\ 0 & \text{for } h_B \le h_{Roof} \end{cases}$$

3.6 Stanford University Interim (SUI) Models:

This model was developed under the IEEE 802.16 working group as part of a proposed standard for frequency bands below 11 GHz.

SUI model is a path loss model developed by Stanford University .Their applicability is for higher frequencies. The SUI models are divided into three types of terrains, namely A, B and C. Type A is associated with maximum path loss and is appropriate for hilly terrain with moderate to heavy foliage densities. Type C is associated with minimum path loss and applies to flat terrain with light tree densities. Type B is characterized with either mostly flat terrains with moderate to heavy tree densities or hilly terrains with light tree densities. The path loss equation is :

$$PL = A + 10log_{10}\left(\frac{d}{d_0}\right) + X_f + X_n + S \qquad for\ d > d_0$$

where the parameters are: d: Distance between BS and receiving antenna [m], d_0: 100 [m], λ: Wavelength [m], X_f: Correction for frequency above 2 GHz [MHz], X_h: Correction for receiving antenna height [m], S: Correction for shadowing [dB], γ: Path loss exponent.

$$A = 20log_{10}\left(\frac{4\pi d_0}{\lambda}\right)$$

$$\gamma = a - bh_b + \left(\frac{c}{h_b}\right)$$ *hb* is the base station antenna height in meters

$$X_f = 6.0log_{10}\left(\frac{f}{2000}\right) \quad for\ terrain\ A\&B$$

$$X_f = -10.3log_{10}\left(\frac{h_r}{2000}\right)$$

$$X_h = -20.0log_{10}\left(\frac{h_r}{2000}\right) \quad for\ terrain\ C$$

f is the operating frequency in MHz, and *hr* is the receiver antenna height in meter
The parameter values of different terrains are:

$$a = \begin{cases} 4.6 & terrain\ A \\ 4.0 & terrain\ B \\ 3.6 & terrain\ C \end{cases}$$

$$b = \begin{cases} 0.0075 & terrain\ A \\ 0.0065 & terrain\ B \\ 0.005 & terrain\ C \end{cases}$$

$$c = \begin{cases} 12.6 & terrain\ A \\ 17.1 & terrain\ B \\ 20.0 & terrain\ C \end{cases}$$

3.7 ECC-33 Model:

The ECC-33 model is an extrapolated version of the original measurements made by Okumura model. The COST-231 model extended its use up to 2 GHz but it was proposed for mobile systems having omni-directional CPE (Customer Premises Equipment) antennas sited less than 3 m above ground level. This path loss model was developed by Electronic Communication Committee(ECC),is extrapolated from original measurements by Okumara and modified its assumptions so that it more closely represents a Fixed Wireless Access(FWA)system. Path loss is defined as:

$$PL(dB) = A_{fs} + A_{bm} - G_t - G_r$$

where, A_{fs} is free space attenuation in dB, A_{bm} is basic median path loss in dB, G_t is transmitter antenna height gain factor and G_r is receiver antenna height gain factor.

$$A_{fs} = 92.4 + 20log_{10}(d) + 20log_{10}(f)$$

$$A_{bm} = 20.4 + 9.83log_{10}(d) + 7.89log_{10}(f) + 9.56[log_{10}(f)]^2$$

$$G_t = log_{10}\left(\frac{h_b}{200}\right)\left[13.98 + 5.8(log_{10}(d))^2\right]$$

$$G_r = [42.57 + 13.7log_{10}(f)][log_{10}(h_m) - 0.585]$$

where, d is the distance between transmitter and receiver antenna in kms, f is frequency in GHz, hb is transmitter antenna height in meter and hr is receiver antenna height in meter.

IV. CONCLUSIONS

The paper includes the discussion of various propagation models in NS3. Models considered are: FRIIS Propagation Loss Model, Log Distance Model, Jakes Propagation Loss Model, Nakagami Propagation Loss Model, COST-231 Walfisch Ikegami Model, Stanford University Interim (SUI) Models, and ECC-33 Model. These models can be implemented by considering parameters like shadowing, path loss and multipath. Emulation can also be done for these models using WiMax.

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