Signals and Communication Technology

IP-Traffic Theory and Performance

Bearbeitet von
Christian Grimm, Georg Schlüchtermann

1. Auflage 2008. Buch. xiv, 487 S. Hardcover
ISBN 978 3 540 70603 8
Format (B x L): 0 x 0 cm
Gewicht: 914 g

Weitere Fachgebiete > Mathematik > Numerik und Wissenschaftliches Rechnen > Angewandte Mathematik, Mathematische Modelle

Preface

Reading without meditation is sterile;
meditation without reading is liable to error;
prayer without meditation is lukewarm;
meditation without prayer is unfruitful;
prayer, when it is fervent, wins contemplation,
but to obtain contemplation without
prayer would be rare, even miraculous.

Bernhard de Clairvaux (12th century)

Nobody can deny that IP-based traffic has invaded our daily life in many ways and no one can escape from its different forms of appearance. However, most people are not aware of this fact. From the usage of mobile phones – either as simple telephone or for data transmissions – over the new form of telephone service Voice over IP (VoIP), up to the widely used Internet at the users own PC, in all instances the transmission of the information, encoded in a digital form, relies on the Internet Protocol (IP). So, we should take a brief glimpse at this protocol and its constant companions such as TCP and UDP, which have revolutionized the communication system over the past 20 years.
The communication network has experienced a fundamental change, which was dominated up to end of the eighties of the last century by voice application. But from the middle of the nineties we have observed a decisive migration in the data transmission.
If the devoted reader of this monograph reads the title 'IP traffic theory and performance', she/he may ask, why do we have to be concerned with modeling IP traffic, and why do we have to consider and get to know new concepts. She/he may argue that on the one hand, since the early days of Erlang and his fundamental view on the traffic description in the emerging communication world, formulas and tables have contributed to the building of powerful communication networks. On the other hand she/he may be guided by the argument that, even if we do not meet the correct model, i.e. if our standard knowledge does not suffice and fails, there is enough technical potential in the classical telecommunication network, in terms of equipment, to overcome any bottleneck.
In some respect, we will disprove this misleading attitude. But before going into details, we can already argue that on the one side, and this is done in several parts of the monograph, IP-based traffic does not fit into the classical framework of the Erlang theory. Since the network connections is no longer

end-to end built, but it is chaotic at the first glance, and that is the strength of the IP-based networks, since the Internet is *self-organized*, i.e. deciding more less at each router or node, which route it will take. This introduces the stochastic aspect, which runs through the IP modeling as well through our book as a dominant feature.

On the other side making server or router as powerful as possible so as to make any modeling superfluous, has its decisive drawback. The network is not clearly structured, so that at each possible node, the capacity and service rate is large enough to encounter any traffic load. Only a few bottlenecks diminish the performance and would especially influence extensively the time sensitive traffic, as Voice over IP or video streaming, with its strong quality of service (QoS) requirement. The customer would avoid any of these services as a consequence. This in fact has occurred already in reality and is not a fiction. Incorrect design of networks according to IP traffic requirements lead to a rejection or at least an unexpected delay of new services like VoIP or video on demand.

In addition, a variety of technical possibilities raises more expectations: if we have the traffic capacity, we want, and we will use it without restriction – and in turn the network will meet its limits soon. Avoiding these difficulties and being prepared for future challenges, we present models, indicate consequences and outline major key aspects, like queueing for judging performances of the network.

After the discovery of the Bellcore group in the early 1990's it was Ilkka Norros who developed a first approach in describing the IP-based traffic. He used the fractional Brownian motion as stochastic perturbation to incorporate the basic phenomena of self-similarity and long-range dependence of the connectionless traffic. As already mentioned this is in contrast to the classical circuit switched traffic, where averaging over all scales is leveling the bursty character – this bursty character does not change over all time scales in the IP case.

In fact, this approach was not new, since in the sixties Benoît Mandelbrot and John Winslow Van Ness used the fractional Brownian motion and its self-similarity for the description of stock pricing in financial markets. The race for the most appropriate model was opened! A significant variety of models was introduced, which is a consequence of the fast growing number of applications accompanied by different protocols, especially with the TCP/IP. Some tried to describe the large scales and the more Gaussian traffic, other the more bursty traffic and again others the small scales influenced by the control cycle triggered by the TCP/IP. Here, especially the multifractal models and cascades entered the scene, with some of course relatively complicated and with the lack of a suitable chance for application. Up to now a unified theory is missing, which of course may not be near to fulfillment, since the variety of modern networks counteracts these efforts.

Hence, we will present the major models and indicate their advantages and limitation. It is clear that it would be beyond the scope of the book to give a full list of all approaches. It is our aim on the one hand to give a certain

feeling, why the IP traffic differs from the classical Erlang description, to give insight into the different approaches, where of course we will to some extent only introduce them and will not go into details. This is left to the reader for further study. We will show, how one can map the traffic to the models using standard statistical methods and we will finally try to answer the question, as to what are the decisive key values, like queueing, waiting time and QoS thresholds. These factors enter finally into the major question of optimization – from the network point of view as well as from the economical standpoint.
Summarizing we do not pursue completeness or even a full and profound description of all existing models for IP traffic. In fact, we would like the monograph to be considered as a 'window not mirror' as Rainer Maria Rilke in his 'testamony' once put it [79]. Writing the book was for us like the metaphor of Rilke, with only a small 'window hole' compared to the huge building of nature.
The book is organized as follows: We start with the fundamental ingredients and properties of the IP-based traffic and its resulting concepts and models. The second chapter is, what we call the classical traffic theory. We build up the foundations from the well-known Erlang formulas and the resulting basic ideas of telecommunication traffic in the circuit switched context to the new development of incorporating phase distributed approaches for inter arrival and service times. In addition, deterministic approaches mixed with probability aspects applied to the control cycles and stochastic influences of the chaotic structure of the network, will be considered as well.
As illustrated in the first chapter, the basic phenomena in IP traffic can be described as *self-similarity* and *long-range dependence*. Already outlined in chapter 2, the traffic is determined by stochastic perturbation. Thus, we have to deal with the basic stochastic processes as fractional Brownian motion (FBM), the FARIMA time series and fractional α-stable processes and its key value, the *Hurst exponent*. Their influence and significance in the IP traffic will be outlined in the sequel, one using the approach with stochastic differential equation (like the Norros approaches) and the other from a more physical point of view. Finally, we incorporate the protocol influence which leads to the multifractal Brownian motion (mBm) or the pure multifractal models.
To implement the models for a given observed network, we have to collect different samples of data and analyze them using standard statistical methods. This is especially important for estimating one key value, the Hurst parameter. Methods like the absolute value, the Whittle and wavelet estimator are to be mentioned. But, as the entire monograph demonstrates, no method is the dominant and fundamental one. The preferred model as well as the estimation methods depends on the particular application.
Finally, in the fifth chapter, we consider the major field of application for each of the various models – the performance and optimization aspect. Within the narrative, we present key models, like the Norros and multifractal approaches, and its influence on the performance key values. In conclusion, we apply this to the optimization under some selected aspects. The last section follows more

or less the idea of fair prices introduced by Kelly, Maulhoo and Tan [138] and we apply this together with the special perturbation of the FBM. Here, we select the toolbox for optimal control, developed in mathematical economy. Since most approaches require mathematics for a suitable description, evitable, the reader should be familiar with some key concepts, such as differential equations, probability theory, and stochastic analysis. It should be mentioned that we have tried to keep most techniques as simple as possible, to avoid burdening the reader with details. These details and a more profound understanding is left to the interested reader in the specific monographs or the original literature. But the mathematical toolbox is essential and it seems suitable to cite Galileo Galilei:

> *The book of nature can only be understood, if we have learned its language and letters, in which it is written. And it is written in mathematical language and the letters are triangle, circles and geometrical figures; without those auxiliaries it is not possible for mankind to understand a single word.*

Even though geometry does play only a minor role for us, we can transfer the idea behind Galilei's words to the analytical field in mathematics, used for this monograph.

Hannover and München *Christian Grimm*
May 2008 *Georg Schlüchtermann*