NETWORK CONTROL OF SATELLITE COMMUNICATION SYSTEMS

Michael H. Aronson
Ford Aerospace & Communications Corporation
3939 Fabian Way
Palo Alto, California 94303

ABSTRACT

This paper provides an overview of network control concepts applied to satellite communications systems. The term network control is defined, the rationale for employing network control is discussed, and the techniques for controlling a satellite communications system are described. Future trends in the technology are identified.

INTRODUCTION

Network control is the process of maximizing the use of resources in a communications system in order to communicate as much data as possible within the capability of the resources while maintaining an acceptable quality of communication. Significant benefits can be obtained by having a network control capability in commercial as well as military communications systems. This paper describes network control techniques utilized to maximize communications throughput and discusses the trends in technology for the future.

NETWORK CONTROL OPERATION

Network control systems (see Figure 1) operate by measuring certain parameters and then issuing control commands based on these measurements to improve system utilization. A new set of measurements are then taken to note the effect of the commands previously issued. If the new measurements indicate that the prior commands did not completely achieve the desired effect, or if some situation has occurred which has negated the effect of these prior commands, a new set of commands will be issued by the control system. This cycle of measurements and responses continues repetitively to maintain system operation in a near-optimal state. Network control systems rely heavily on computers and software to accomplish the control cycle.

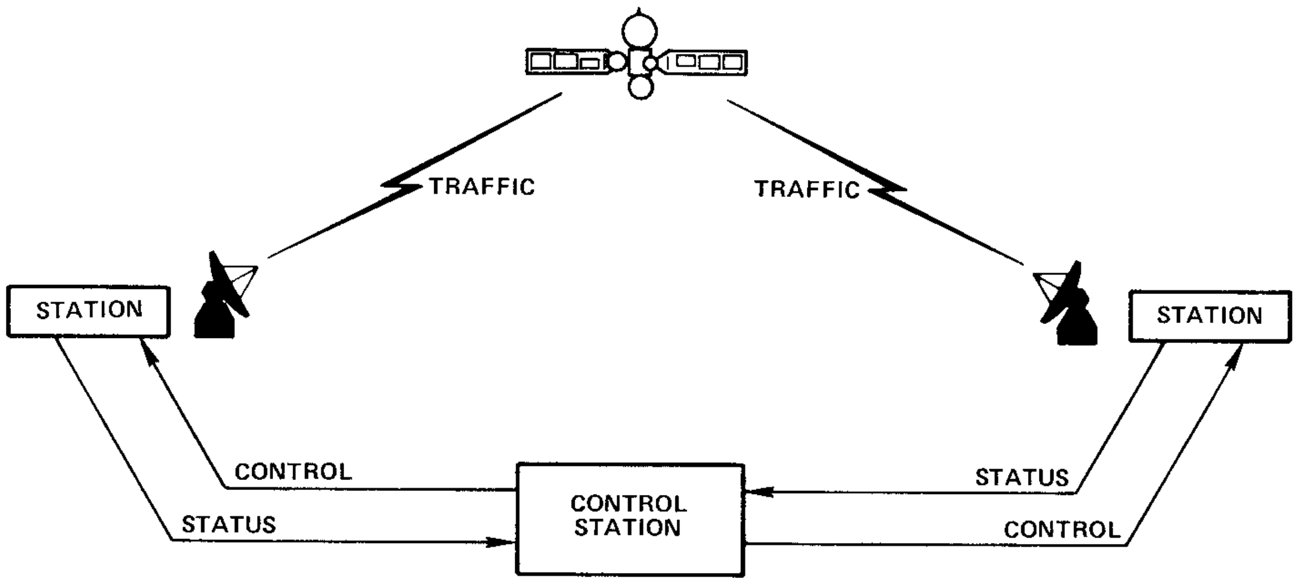

Figure 1. Network Control System Elements

Some of the parameters which are measured or observed by the network control facility in a satellite communications system include requests for transmission channels, data error rates for received signals, power of a beacon reference signal from the satellite, telemetry from the satellite, and the operational status of the equipment used at the transmit and receive earth terminals. The control system computers process this information and generate commands, if necessary, to assign transmission channels on an “as-needed” basis, change the power of individual data links radiated by the earth terminal transmitter, control the rate at which data is exchanged between the source and destination, and may even disconnect a user of the system if deemed necessary.

Importance of Network Control

The key motivations for employing network control are:

1. Provide the best quality of communications available from a given system.

2. Ensure that the communications needs of the users are met.

3. Maximize the return on capital invested, in terms of revenue earned or service provided.

Each of these is discussed in more detail.

Quality of communications for data is determined by the number of errors in the received information compared to the transmitted data which, by definition, was error free. For voice, the quality of transmission is determined by the listener's ability to recognize and understand the speaker. In a satellite communications system a common source of transmission errors is the lack of sufficient signal power at the receiving ground terminal compared to background noise. If the received signal is strong, the background noise is negligible. However, if the signal strength fades, background noise increases and the quality of communications degrades, possibly below a level acceptable to the listener. A typical cause of signal fades is absorption of signals when passing through rain. If rain occurs over the transmit or receive earth terminals, part of the energy in the signal will be absorbed by the rain. Less power will be received compared to background noise and data errors and voice misinterpretations may become unacceptable. Modern network control systems, however, automatically sense the decreasing quality of received signals and command the transmitting terminal to increase its emanated signal level to compensate for the absorption by the rain cloud. When the rain ceases, the control system observes that the received quality is becoming unnecessarily good (no rain attenuation), and commands the transmitting station to lower its transmission level. In a large satellite communications system there may be dozens of earth terminals, with rain occurring simultaneously over many of them. The control system cannot arbitrarily command each affected transmit terminal to increase its power, since this may result in too much power being received at the satellite. When this situation exists, serious interference between signals can occur within the spacecraft communications equipment. The network control system monitors telemetry from the satellite to ensure that the control commands to earth terminals which compensate for rain attenuation are not causing other problems at the spacecraft. This complex process is transparent to the users of the system, who are protected from degradations in service quality.

Both commercial and military systems must consider the effects of rain attenuation on the quality of communications. In a military satellite communications system, however, other sources of degradation may be present. These consist of jamming signals by unfriendly powers which are equivalent to an artificial increase in the background noise level. The desired signal is received with more errors, and quality of communications can degrade to an unacceptable level. With commercial users an interruption in service is an annoyance and may have profit implications. With military users some level of communications must be maintained at all costs, since lives and national interests may be jeopardized.

Network control capability can meet the military user need for uninterrupted service by automatically detecting the presence of a jamming signal. It does this by examining the radio frequency spectrum with a computer-controlled spectrum analyzer and uses sophisticated signal analysis algorithms for detecting the presence of the jamming signal. The control system computer correlates the results of the spectrum analysis with unusual changes in received signal quality reported by the ground terminals. The network control system will then issue commands to the terminals to respond to the jammer. The jamming signal may focus on one or two communication signals in the system, may cause low-level interference for harassment purposes, or may attempt to disrupt all communications. In addition, the waveform of the jammer may take many shapes, some of which are difficult to distinguish from the background noise. The network control system will detect the various types of jammers, and will generate commands to the communications earth terminals which respond appropriately to the current threat level. This could include discontinuing service for nonessential users, decreasing data transmission rate for critical users (this helps the receive terminal correctly interpret the data), and concentrating all available station transmitter power into the remaining critical user communications links. The control system must also determine when the jamming threat is no longer present in order to restore the system to its normal level of service. The automatic detection and response to a jamming threat is a major function of network control in a military satellite communications system.

Communications system assets are becoming increasingly sophisticated and increasingly costly. The system manager must ensure that the capital investment is utilized to its maximum potential, and that available capacity is not wasted. In a commercial system, obtaining extra capacity from a fixed asset translates directly into added revenue and profits. In a military system, demands for service (particularly in wartime) always exceed the available capability. Extra capacity from the fixed asset translates into more military forces which are provided with needed communications. It was mentioned previously that rain over a transmit or receive earth terminal will attenuate signals and degrade the quality of service. Prior to automated network control, the satellite communications system would be operated with 25% of the satellite power dedicated to providing service, and 75% of the power placed in the same signals as margin to protect against rain fades. If the signal experienced rain attenuation, the signal strength would be reduced; however, since it was so much stronger than necessary to provide acceptable quality due to the power margin, the user would not experience a degradation. This is wasteful of satellite power, and limits the number of links between users which can be supported at any given time. Ford Aerospace has implemented a network control system which has automatic rain fade control, permitting the margin in the system to be cut in half. The satellite power available to support other users was increased by 100%, a substantial increase in capacity. It is estimated that a savings of $8 in satellite cost was achieved for each dollar invested in the network control system by increasing the capacity of the satellite to carry traffic.

Another approach to maximizing the return on investment is to utilize the satellite communications channels on as close to a full period basis as possible. In some systems a channel is assigned to a ground terminal whether or not data is available for transmission. More efficient systems assign a channel only when the ground terminal indicates to the network control system that it has a call pending. This permits a small number of channels to satisfy the needs of a large terminal population, reducing the amount of expensive spacecraft communications equipment. Control of accesses to the satellite is another aspect of network control.

TECHNOLOGY TRENDS

Network Control systems implemented to-date are automated and primarily centralized. As processor costs decrease and software development costs also decrease due to improved development methodologies, network control systems of the future will become increasingly automated, and will be decentralized. A control center may exist for administrative purposes and to perform history analysis of system performance. However, control will be coordinated directly between the transmit and receive earth terminals with a spacecraft computer mediating conflicting demands from the earth terminal network. This includes the assignment of an available channel on an "as-needed" basis, as well as the routing of traffic to its destination by the satellite. The satellite processor will assume greater responsibility for detection of jamming and for determining what to do about the jammer. In some cases, the satellite will attempt to null out the jamming signal by adjusting its antenna beam locations. In other cases, the spacecraft will request reconfiguration of the earth terminal equipment to assist in defeating the jamming signal.

As higher transmission frequencies are used, such as extremely high frequency (EHF), the effects of rain attenuation become more severe. This applies to both the depth of fade as well as the rate of fade. The spacecraft processor will become increasingly involved in detecting rain fades and in controlling the terminal and its own transmit levels to compensate accordingly. In order to avoid operating the system with very large margins, a rapid-response control system consisting of the spacecraft and the earth terminals will evolve. More automation will be required due to the real-time requirements for measurement of status and generation of control responses in fractions of a second.

At the earth terminals more of the station equipment will incorporate embedded microprocessors, negating the need for a station computer. The microprocessors within a station will communicate with each other as well as with microprocessors at other earth terminals. Earth terminals will be operated unmanned, relying entirely on the microprocessors in the station equipment and the spacecraft processor to run the system. In order for network control to be employed extensively in commercial as well as military systems, the control hardware must become a small fraction of total hardware cost. Key to this is the need for inexpensive microprocessors which can be incorporated directly into the communications equipment. These microprocessors, through very large scale integration (VLSI), will be reduced to one or two electronic chips which can be mounted in any convenient location on a printed circuit board in the various communications equipment chassis. Current microprocessors have separate chips for the processing unit, memory, and external interfaces. These will be combined into very small packages in the near future.

Future network control systems will employ data bases which are distributed throughout the system. Pieces will reside in the various equipment components at a communications station, at the control centers, and parts will reside in the communications satellite. In these systems data must be updated simultaneously at various points in the system, and one location can ask for information that resides in a data base at another location. The technology of truly distributed data bases is only now being explored by universities and industry. Work is focusing in the areas of synchronizing data base updates throughout the system, techniques for partitioning the data base into its many geographically separate elements, and identifying specific software functions which will support distributed data bases. In addition, future communications protocols and software design will ensure that data base updates and data requests/responses propagate through the system without errors.

CONCLUSION

This overview has described network control concepts and has shown the importance of network control to modern communications systems. In addition, future trends in the technology were discussed. Network control systems provide significant benefits in terms of increased system performance and optimum system utilization. It is expected that more and more communications systems will employ automated network control in the future.

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