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O. L. Synyavsky, D. I. Cherkasov, V. Kyrylko

NON-UNIFORM SIMULATION MODELING OF A LARGE-SCALE CABLE PLANT

Building data-over-cable networks (DOCN) provides highly functional and efficient infrastructure which enables supplying Internet or other information services to large numbers of customers which connect to network with cable modems. Contemporary DOCN may include millions of cable modems therefore the task of managing the network is rather complicated. To provide a proper control of DOCN a special set of hardware and software tools is used which may be referenced as a cable plant managing unit (CPMU).

It is significant that any newly designed CPMU be thoroughly verified in all aspects of its operation before using it in a real DOCN. To perform such verification CPMU being verified must be put in an environment which resembles real DOCN as close as possible.

As DOCN include a great number of cable modems and expensive cable modem termination systems (CMTS) it is practically impossible to provide a large-scale DOCN for laboratory testing. On the other hand it is undesirable to perform any elaborate tests using any real running DOCN with multiple customers being connected as it may lead to degrade in the quality of service.

Possible solution for the verification of CPMU for a large-scale DOCN is using a cable plant simulation system *(CPSS) which helps to perform all the necessary checking and verification of the CPMU without using a real DOCN.*

Introduction

Figure 1 illustrates the basic diagram of *data-over-cable network* (DOCN).

DOCN incorporates the following parts:

- *cable plant managing unit* (CPMU);
- *head end* which incorporates multiple *cable modem termination systems* (CMTS), and additional services such as servers of Dynamic Host Configuration Protocol (DHCP), Trivial File Transfer Protocol (TFTP) and Time-Of-Day (TOD);
- *cable plant* which incorporates multiple *cable modems*.

CPMU performs *cable plant* management through SNMP negotiation with CMTS and *cable modems.*

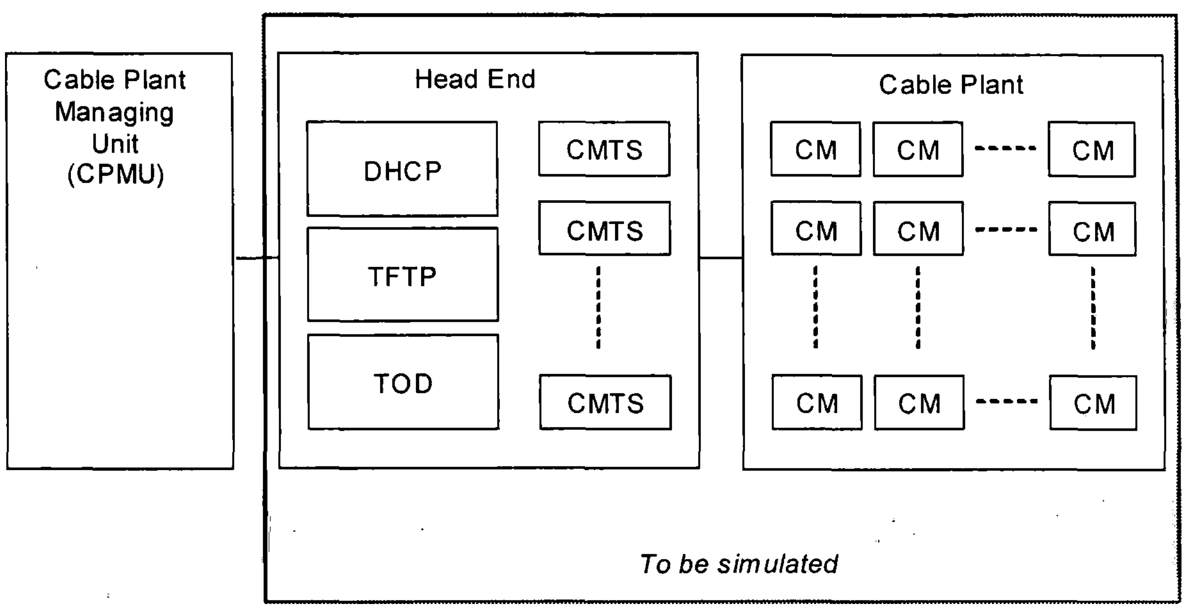

Figure 1. Data-over-cable network (DOCN)

There are three aspects of CPMU operation that need to be tested:

- protocol verification,
- logic verification,
- performance capability.

Protocol verification is aimed at checking CPMU accordance with standard specifications such as SNMP. Timing and standard SNMP operations over local area network (LAN) connection are checked at this stage.

Logic verification considers checking whether the CPMU operates strictly according to implemented algorithms and is free from unpredictable and uncontrolled states (deadlocks, etc.).

The target of testing the performance capability is to verify whether the system being tested is capable to handle expected load and may be used to manage DOCN of particular scale.

In order to provide CPMU testing in all of the mentioned aspects a special simulation module is provided which closely simulates the DOCN environment to CPMU being tested. CPMU and simulation module to which CPMU is connected form an integral environment which is referenced as a *cable plant simulation system* (CPSS).

The demands to CPSS include:

- identity of network interface between CPMU and simulation module to the interface for CPMU in a real DOCN;
- simulation of all kinds of events and modes of operation of DOCN;
- simulation of operation of DOCN of various scales with various numbers of *cable modems* and CMTS;
- real-time simulation in accordance with timings of a real DOCN of any particular scale;
- convenient and efficient operator's interface which provides setting the properties of assumable DOCN, starting particular tests and getting their results as well as exhaustive online monitoring.

It is also highly desirable that CPSS reflects the current state-of-the-art in DOCN design as well as possible trends in future DOCN development.

Approaches

The most significant and complicated part of CPSS development is providing "realistic" simulation of SNMP negotiation between CPMU and *cable plant* without using of real *cable modems*.

DOCN in general presents a particular case of a concurrent process system. There are several known approaches to simulate concurrent process systems using software models executed on high-performance computers and computer clusters.

The Scalable Simulation Framework (SSF) [1] is a Java and C++ based API for the description of network models. The objectives of SSF are to provide a standard of discrete event simulation of large complex systems.

Dartmouth SSF (DaSSF) [2] is a process-oriented, conservatively synchronized parallel simulator, which is designed for simulating large scale multi-protocol communication networks. DaSSF is a C++ implementation of Scalable Simulation Framework (SSF). DaSSF runs under a variety of architectures including SGI IRIX, SUN Solaris, DEC OSF, Linux and Windows. Parallelization is supported through shared memory on all these platforms. DaSSF also supports parallel simulation on distributed memory clusters.

MIMIC Simulator Suite [3] developed by Gambit Communications ™ creates a customizable virtual environment populated with devices like routers, hubs, switches, probes, cable modems and workstations. The MIMIC Simulator suites include C++, Java, Perl, Tel modules for simulating particularly general SNMP objects and cable modems.

The AdventNet Simulation Toolkit [4] provides a comprehensive set of tools for creating a simulated environment. It supports setting up a simulated agent and simulating an entire network in Windows, Linux and Solaris. In addition it provides a rich set of utilities which help in setting up a simulated network.

Such simulation systems which are based on executing integrated software model on a single computer or cluster we reference as *uniform simulation systems*.

Common drawback of *uniform simulation systems* which eliminates their effective usage for *cable plant* simulation is that while simulating closely the algorithms of DOCN they are not able to provide simultaneously equally realistic simulation of all the levels of DOCN operation ranging from low-level network negotiations to high-level processes with real timings. Based on developing the integral model consisting of smaller components models they require simulation of low-level components to provide "realistic" low-level operation simulation. Obviously, low-level simulation of large-scale systems requires vast processing resources.

The proposed approach referenced as a *non-uniform simulation system* considers decomposing the whole simulation system into multiple layers each of which is responsible for a particular level of simulated system operation. Different layers are implemented independently possibly using different hardware and software basis. The parts responsible for the simulation of the lower levels may be implemented using custom equipment that provides

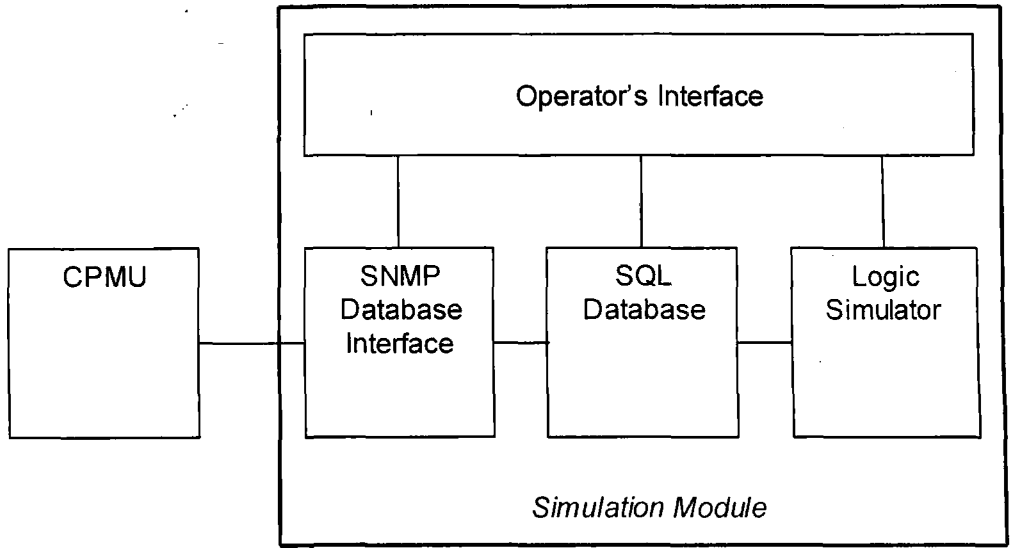

Figure 2. Cable Plant Simulation System (CPSS)

necessary performance at those levels of operation. Also for simulation of high-level algorithm of operation it is suitable to use *uniform simulation systems.*

Architecture

Figure 2 illustrates the basic diagram of CPSS implementing a *non-uniform simulation approach.*

CPSS incorporates the following components:

- CPMU;
- *SNMP database interface;*
- *SQL database;*
- *logic simulator,*
- *operator's interface.*

SNMP database interface, SQL database and logic simulator present three layers of simulation.

SNMP database interface incorporates mainly hardware components which provide low-level LAN interface to CPMU and operate at a speed of a real *cable plant. SNMP database interface* performs the conversion of the control instructions passed from CPMU to *head end* and *cable plant* into the data setting or retrieval requests for the *SQL database.* It also converts the data retrieved from the database into the form similar to response of *head end* and *cable plant* to CPMU.

SQL database stores the control information in accordance to SNMP Management Information Base (MIB) of *cable modems* and CMTS.

Logic simulator provides the simulation of the operating algorithm of *cable plant.* It checks the data in *SQL database* for the instructions from CPMU and sets data to be passed to CPMU.

CPSS may be used for simulation in its complete architecture or partially depending on the task of simulation.

When simulating only the SNMP basic negotiation CPSS may incorporate only *SNMP database interface.* SNMP instructions from CPMU are accepted by the *SNMP database interface* but no action is taken. Some void values are passed to CPMU on the requests for SNMP data.

More elaborate simulation adds to CPSS *SQL database.* The structure enables to simulate the exchange of more or less "realistic" data. Operation of CPMU with any particular MIB may be simulated in this configuration.

Adding the *logic simulator* which is able of analyzing and changing the data in the *SQL database* makes the CPSS perform SNMP negotiation absolutely similar to real cable plant.

All the components of the CPSS are controlled and monitored via the *operator's interface* implementation of which is beyond the scope of this paper.

Implementation

SNMP database interface may be implemented as a single or multiple UNIX hosts connected with a switch.

SQL database may be implemented as a single database engine or database cluster.

Logic simulator implementation may incorporate some *uniform simulation system,* for example discrete-event or fluid-flow simulation models. It may also use application-specific software modules such as front-end block of Simulation Framework "DOCSIS compatible inquire converter and response shaper". *Logic simulator* may run on distributed processing system, which consists of a collection of interconnected stand-alone computers operating as a single integrated computing engine.

Conclusions

The task of verification of CPMU for contemporary DOCN requires a high-performance simulation system that provides realistic modeling of a cable plant with real timings.

Developing of such a system based on *uniform simulation system* involves considerable amount of expensive high-performance hardware components such as super-computers and computer clusters.

Presented approach of using *non-uniform simulation system* enables decomposition of the developed simulation system into several layers each of which simulating different aspects of cable plant operation. Independent design of every layer provides the possibility of using them in various sets therefore enabling testing of any particular aspects of CPMU operation.

Independent design of every layer facilitates the task of providing high scalability. The components that most influence the timing of negotiations between CPMU and *cable plant - SNMP database interface* and *SQL database* may incorporate multiple independent nodes operating in parallel.

The simulation of low-level aspects of *cable plant* operation is moved to appropriate layers and therefore *logic simulator* may be developed at the most possible abstract presentation of cable plant operation. That considerably reduces the requirements for computing performance and complexness of *logic simulator*.

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Синявський О. Л., Черкасов Д. 1., Кирилко В.

НЕОДНОРІДНЕ ІМІТАЦІЙНЕ МОДЕЛЮВАННЯ КАБЕЛЬНИХ МЕРЕЖ ВЕЛИКОГО РОЗМІРУ

Технологія кабельних мереж: передачі даних зумовлює можливість створення високофункціональних та ефективних інфраструктур для надання послуг Інтернет або інших інформаційних послуг великій кількості споживачів, що під 'єднані до мережі за допомогою кабельних модемів. Сучасні кабельні мережі передачі даних можуть містити мільйони кабельних модемів. Для керування мережею використовуються високопродуктивні та складні технічні засоби, які утворюють комплекс керування кабельною мережею. Відлагодження таких комплексів у лабораторних умовах є надзвичайно складним завданням, що пов 'язано зі складністю моделювання реального середовища функціонування комплексу. Пропонується декомпозиція задачі моделювання кабельної мережі з використанням окремих засобів для моделювання різних аспектів її функціонування. Запропоновані компоненти моделі інтегровані в єдину систему моделювання кабельної мережі передачі даних. Підхід забезпечує добре масштабування системи моделювання, що надає можливість тестування навантажувальної спроможності комплексів керування.