An Integrated Prototyping and Simulation Architecture for Space Specific Protocol Developments and Verifications

Fraunhofer Institute for Open Communication Systems
An Integrated Prototyping and Simulation Architecture for Space Specific Protocol Developments and Verifications

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Outline

Introduction
- Project Framework
- System Design with Reduced Development Costs

System Architecture
- Integrated Development Flow (Overview)
- Simulation on Network Level
- Protocol Prototyping and Verification

Use Cases
- ATM-Sat MAC Protocol Development
- ATM connectivity between ISS Columbus and Earth

Summary & Outlook
Introduction

Project Framework

ATM-Sat Project
- System Design and Study of an ATM-based LEO Satellite System for Multimedia Applications
- Financed by German Ministry for Education and Research (BMBF)

ATM-Sat Partners
- German Aerospace Agency (DLR), and
- Tesat Spacecom (formerly BOSCH SatCom)

Project Constraints
- None: ATM-Sat mere research project
- Commercial aspects discussed: reduce development costs while still designing failure save systems
## Introduction

### System Design with Reduced Development Costs

#### Possible Solution
- Usage of commercial off-the-shelf equipment for development and simulation
- Standard operation systems as target systems
- Design re-usable components

#### Integrated Dev. Approach
- Idea by Fraunhofer FOKUS
- Supported by TU Berlin (Research Group for Open Communication Systems, OKS)
System Architecture
Integrated Development Flow (Overview)

System Specification

Orbit description or mere delay information

Delay and elevation angle

Exchange of protocol descriptions / algorithms

satellite channel
emulation
terminal control station
SDLC
optical splitting box
ATM
ethernet (satellite channel)
ethernet (management)
TDLC

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System Architecture
Simulation on Network Level

- Focus on the entire communication network (large scale network simulation)
- Performance evaluation and dimensioning of envisioned system
- Analysis of interaction with other network types
- New protocols and algorithms “encapsulated” in processes and programmed in C
System Architecture
Protocol Prototyping and Verification

Key Features:
- Std. COTS components
- Focus on target system
- FreeBSD 5 current-version

Core Units:
- Sat. channel emulator: Configurable via SNMP
  Adds variable delay
  Packet corruptions
- Protocol Dev. Entity: “External VSAT System”
  Netgraph used for devel.
- Control Station: Time synchronization (NTP)
  Initializes SCE & PDE
Use Cases
ATM-Sat MAC Protocol Development

Development Steps
- Specification (SDL based)
- Simulation (with Opnet)
- Implementation (using the Prototyping and Simulation Architecture)

*Most complex scenario which incorporates all aspect of the integrated design and development work flow and all possible functionalities of the Prototyping and Simulation Environment.*

Opnet Simulation
- Conducted by DLR
- Focus on large scale networks and scheduling

Target System MAC
- Implemented by Fraunhofer FOKUS
- Focus on performance
- Used for demonstrations
Use Cases
ATM-Sat MAC Protocol Development

two terminal in different footprints

- satellite
- satellite channel
- application terminal
Demonstrator
DLC System

DLC layer node with three SAPs (ng_dlc)

convergence layer for ethernet encapsulation (ng_SATtrans)

multiplexer for ATM connections between DLC system and terminal system (ng_mux)

ATM cells from separate PVC for UNI messages are directly forwarded to the DLC layer
Use Cases
ISS Columbus ATM connectivity

User Terminal

DLC System

Channel Emulation: Delay, BER, Shadowing

ng_SATtrans
ng_SATtrans

ng_ether
ng_ether

ether_if
ether_if

ng_socket
ng_ccatm
ng_uni
ng_sscfu
ng_sscop
ng_atm
f/hatm
f/hatm
to/from user terminal
to/from DLC system

to/from DLC system

User Terminal

DLC System
Interaction between Opnet and the Protocol Development Entity

Opnet
- Encapsulates algorithms and protocols in “Process-Nodes”
- Input combination of FSMs (graphical input) and C

PDE
- Applies Netgraph concept of FreeBSD 5.0 current encapsulation of algorithms / protocols
- Encapsulation is by nature split into two files:
  File a) Source code of algorithm / protocol
  File b) Hookup with Netgraph system

Code Sharing
- Currently by hand, restricted to some algorithms
- Common code basis seems to be possible,
- Requires “remapping” function calls
Summary & Outlook

Integrated Simulation & Prototyping System
- Evaluation and dimensioning of entire network
- Protocol development wrt. target system
- Already fully integrated environment for development, testing, and demonstration of target system protocols
- Partial code exchange between Opnet and PDE done, common code basis seems feasible

Future Work
- Common code basis
- Determine how performatory target system code is in the simulator
- Determines on follow-up projects

Further Information
- emmelmann@ieee.org
- http://www.fokus.fraunhofer.de/cats/satellite
### Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>ATM</td>
<td>Asynchronous Transfer Mode</td>
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<tr>
<td>COTS</td>
<td>Commercial Of-The-Shelf</td>
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<tr>
<td>CS</td>
<td>Control Station</td>
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<tr>
<td>DLC</td>
<td>Data Link Control</td>
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<tr>
<td>ISL</td>
<td>Inter-Satellite-Link</td>
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<tr>
<td>MAC</td>
<td>Medium Access Control</td>
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<tr>
<td>PDE</td>
<td>Protocol Development and Prototyping Entity</td>
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<tr>
<td>PVC</td>
<td>Private Virtual Channel</td>
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<tr>
<td>SCE</td>
<td>Satellite Channel Emulator</td>
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<tr>
<td>SDLC</td>
<td>Satellite DLC</td>
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<tr>
<td>TDLC</td>
<td>Terminal DLC</td>
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<tr>
<td>ISS</td>
<td>International Space Station</td>
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<tr>
<td>NTP</td>
<td>Network Timing Protocol</td>
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<tr>
<td>SAP</td>
<td>Service Access Point</td>
</tr>
<tr>
<td>VSAT</td>
<td>Very Small Aperture</td>
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</tbody>
</table>
References & Further Reading

- http://www.fokus.fraunhofer.de/cats/satellite


- http://www.opnet.com
- http://www.stk.com
- http://spacesensors.dlr.de/SE/bird
- http://www.freebsd.org
- http://www.daemonnews.org/200003/netgraph.html
Supportive Slides
Simulation Environment
Simulation Workflow

- Definition of satellite network
  - Orbit altitude
  - Orbit type

- Definition of communication network aspects
  - Bandwidth
  - Bit Error Rates
  - Internet Protocol Suite

STK

AER Data
Parser Programs

Satellite Path Description

p2p-link w/ variable delay

*.c and *.h Files for pipeline stages
Satellite System Architecture

System Parameters

- LEO satellite network
- 70 ... 100 satellites
- One satellite connected to 4 neighbors via optical ISLs (inter- and intra-orbit)
- ISLs existing all the time
- Dynamic bandwidth allocation
- 2400 ... 300000 user per satellite depending on the allocated bandwidth

Uplink bitrate: fixed and portable terminals: up to 2048 kbit/s
Mobile terminals: up to 384 kbit/s in steps of 16 kbit/s
Downlink bitrate: up to 32786 kbit/s in steps of 16 kbit/s
Modulation scheme: QPSK
Access scheme: uplink: MF-TDMA, downlink: TDM
Spotbeam diameter: 50 km – 500 km
Satellite switch capacity: 5 Gbit/s - 10 Gbit/s
ISL capacity: 7 Gbit/s - 10 Gbit/s
Downlink data rate per carrier: 32 Mbit/s
Maximum number of downlink channels per 32 Mbit/s / 16 kbit/s = 2000
standard ATM is used

modified ATM signaling is used due to limited onboard processing power and unnecessary protocol functions

DLC layer with a management interface to upper layer is implemented

Satellite System Architecture
Protocol Architecture

Radio PHY
Radio DLC
ATM
S-AAL
AAL-5
M-UNI
SNMP
ILMI
Call Control
and Resource Management
Satellite terminal
Satellite control plane
user plane
mgmt. plane
control plane
user plane
mgmt. plane
Demonstrator
User Terminal

FreeBSD netgraph subsystem used for entire ATM signaling stack

applications can access ATM directly or via usual TCP/IP

IP realised via CLIP and ATM Forum LAN emulation

local management interface (UNI <-> DLC) implemented via a PVC between the systems

of-the-shelf IP and native ATM applications can be demonstrated
Demonstrator
Control Station

console server for the DLC systems and the ATM switch

signaling VCs are forwarded as PVCs to the control station preforming the signaling

call control daemon is built around an SNMP daemon

management station for the complete demonstrator

can run many tracing tools for measurements

diskless boot support for DLC systems
Demonstrator
Management (Internal Structure)

CGI-Scripts
Apache
Web Browser

HTTP Part
SNMP Part
Translator
HTTP Module

SNMP Module
Netgraph Module
...
...
...

HTTP Text/plain
HTTP Text/html
Netgraph Hook

SNMP
System (Wlink)
SNMP Daemon
SNMP Module
...
...

CGI-Scripts
Apache
Web Browser

HTTP Part
SNMP Part
Translator
HTTP Module

SNMP Module
Netgraph Module
...
...
...

HTTP Text/plain
HTTP Text/html
Netgraph Hook
Demonstrator Management (Graphical User Interface)

Compatible with almost all browsers with frame support

For simplicity, only minimum set of HTML features used

Working Page divided in two zones: top part for navigation and status reports, bottom part for setting parameters

Optional additional reporting windows and periodic refresh