NETWORK MANAGEMENT ARCHITECTURES AND SYSTEMS

HISTORY, STATUS AND FUTURE

AIKO PRAS

DESIGN AND ANALYSIS OF COMMUNICATION SYSTEMS (DACS) GROUP
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ABOUT ME

Associate Professor University of Twente

**Design and Analysis of Communication Systems**

Interest: network management, measurements, security

EMANICS Research leader

IFIP WG6.6 chair

Various journals, OCs etc.

ABOUT DACS
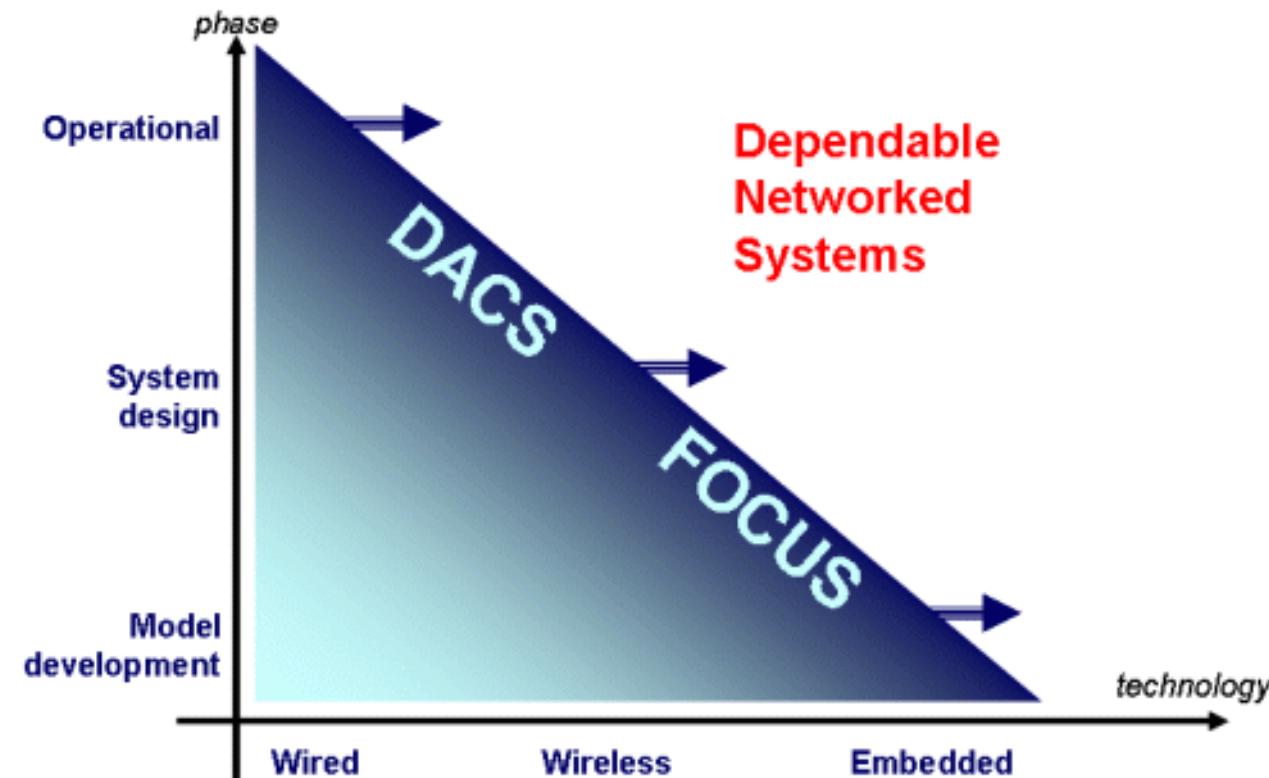
ABOUT EMANICS

European Sixth Framework Network of Excellence
FP6-2004-IST-026854-NoE
1 January 2006 -> 31 December 2009

Management of the Internet and Complex Services

EMANICS themes:
- Management Foundations
- Management Technologies
- Management Applications

EMANICS MEMBERS

**Caisse des Dépôts et Consignations
Institut National de Recherche en Informatique et Automatique
University of Twente
Imperial College
International University Bremen
KTH, Royal Institute of Technology
Oslo University College
Universitat Politecnica de Catalunya
University of Federal Armed Forces Munich
Institute of Bioorganic Chemistry PAS – Poznan
Supercomputing and Networking Center
University of Zürich
Ludwig-Maximilian University Munich
University of Surrey -> University College London**

EMANICS STRUCTURE

Integration Activities	WP0 - Project Management and Scientific Animation
	WP1 - Vision and Integration Programme
	WP2 - Virtual Laboratory and Common Testbeds
Dissemination Activities	WP3 - Conferences Outreach and Education
	WP4 - Electronic Dissemination Environment
	WP5 - Standardization and Technology Transfer
	WP6 - Open Source Initiatives and Joint Software Development
Joint Executed Research Activities	WP7 - Scalable Management
	WP8 - Economic Management
	WP9 - Autonomic Management

OVERVIEW OF TODAY

SNMP STATUS
30 MINUTES

HOW IS SNMP BEING USED IN PRACTICE
30 MINUTES

WHAT ARE THE PROBLEMS OF SNMP
15 MINUTES

OVERVIEW OF NETCONF
15 MINUTES

WEB SERVICES FOR MANAGEMENT
60 MINUTES

KEY CHALLENGES IN
NETWORK MANAGEMENT RESEARCH
60 MINUTES

REFERENCES

- Schönwälder, J. and Pras, A. and Harvan, M. and Schippers, J. and van de Meent, R.
  SNMP Traffic Analysis: Approaches, Tools, and First Results
  In: Proceedings of the Tenth International Symposium on Integrated Network Management, 21-25 May 2007, Munich, Germany. pp. 324-332
  IEEE Computer Society Press. ISBN 1-4244-0799-0, 2007

- Schönwälder, J. and Pras, A. and Martin-Flatin, J.P.
  On the future of Internet Management Technologies
  IEEE Communications Magazine, 41 (10). pp. 90-97. ISSN 0163-6804, 2003

- Pras, A. and Schönwälder, J. and Burgess, M. and Festor, O. and Martinez Perez, G. and Stadler, R. and Stiller, B.
  Key Research Challenges in Network Management
  IEEE communications magazine, 45 (10). pp. 104-110. ISSN 0163-6804, 2007

- Pras, A. and Martin-Flatin, J.P.
  What Can Web Services Bring To Integrated Management?
  In: Handbook of Network and System Administration.
  Elsevier, Amsterdam. ISBN 978-0-444-52198-9, 2007

- Pras, A. and Drevers, T. and van de Meent, R. and Quartel, D.A.C.
  Comparing the Performance of SNMP and Web Services-Based Management
  IEEE transactions on network and service management, 1 (2). pp. 72-82
  ISSN 1932-4537, 2004

- Schönwälder, J
  RFC3535: Overview of the 2002 IAB Network Management Workshop
  May 2003

BACKGROUND MATERIAL

- **PODCAST / REAL MEDIA PRESENTATIONS**
  http://www.simpleweb.org/tutorials/video/

- **SLIDES**
  http://www.simpleweb.org/tutorials/slides.html

- **EXERCISES**
  http://www.simpleweb.org/tutorials/exercises.html

SNMP STATUS

OVERVIEW MANAGEMENT STANDARDS
- CMIP-CMIS

HISTORY
- GENERAL MANAGEMENT PROTOCOLS
- SNMP - OVERALL
- SNMP - RECENT HISTORY

RFCs AND STANDARDS

SNMP PROTOCOL OPERATIONS

OTHERS
- JMX
- TM FORUM
- OASIS
- IEEE
- ...

OVEVIEW MANAGEMENT STANDARDS

ISO
- CMIP-CMIS

IETF
- SNMP (V1-3), SMI (V1-2), MIB Modules
- SYSLOG
- NETCONF

ITU-T
- TMN

DMTF
- WBEM/CIM

OTHERS
- JMX
- TM FORUM
- OASIS
- IEEE
- ...

HISTORY MANAGEMENT STANDARDS
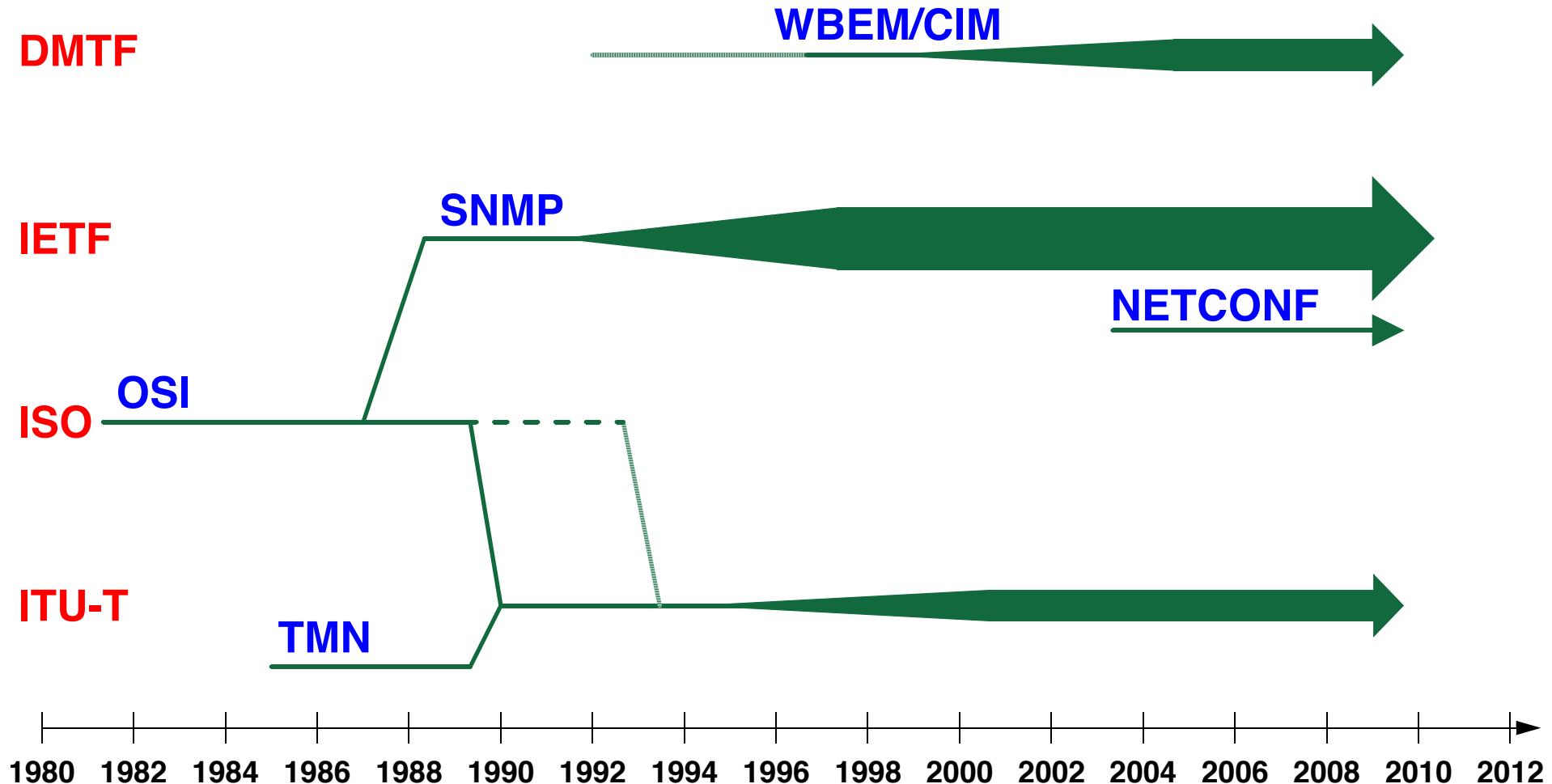
SNMP HISTORY - OVERVIEW
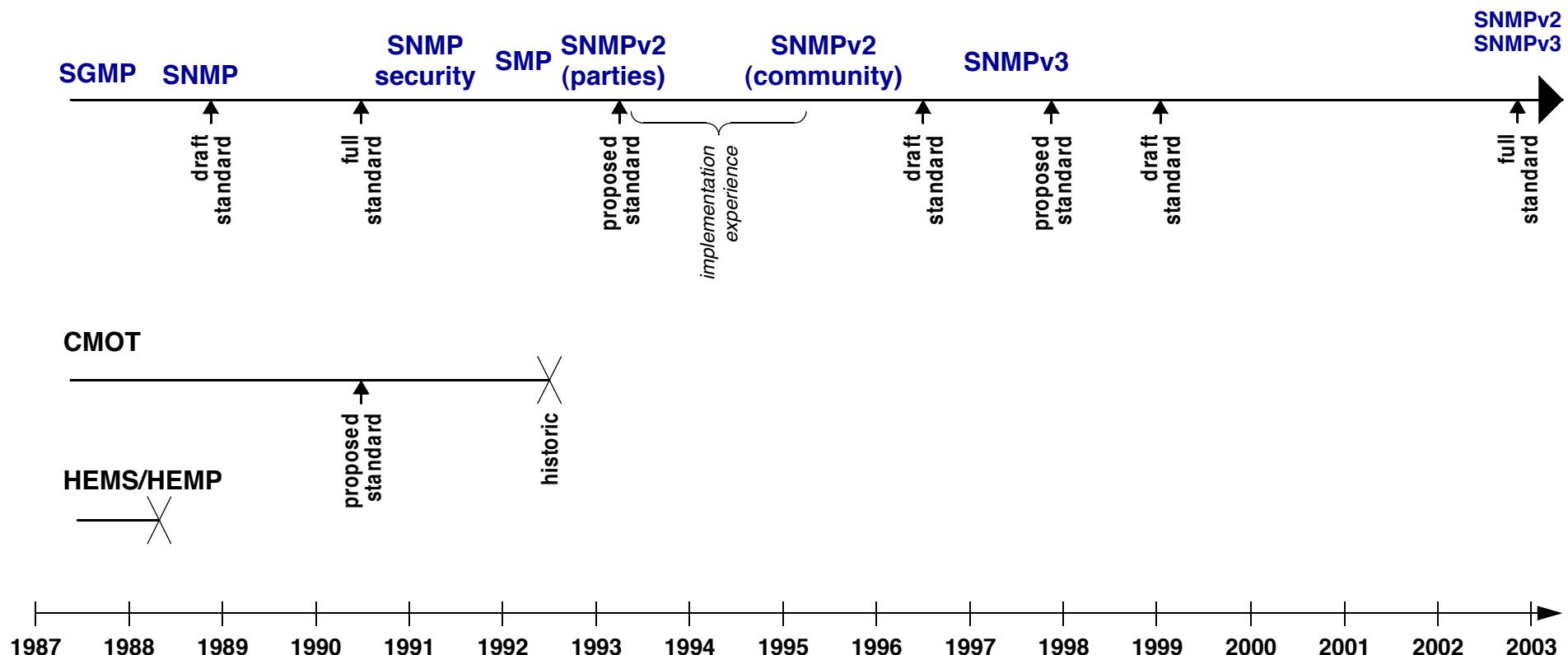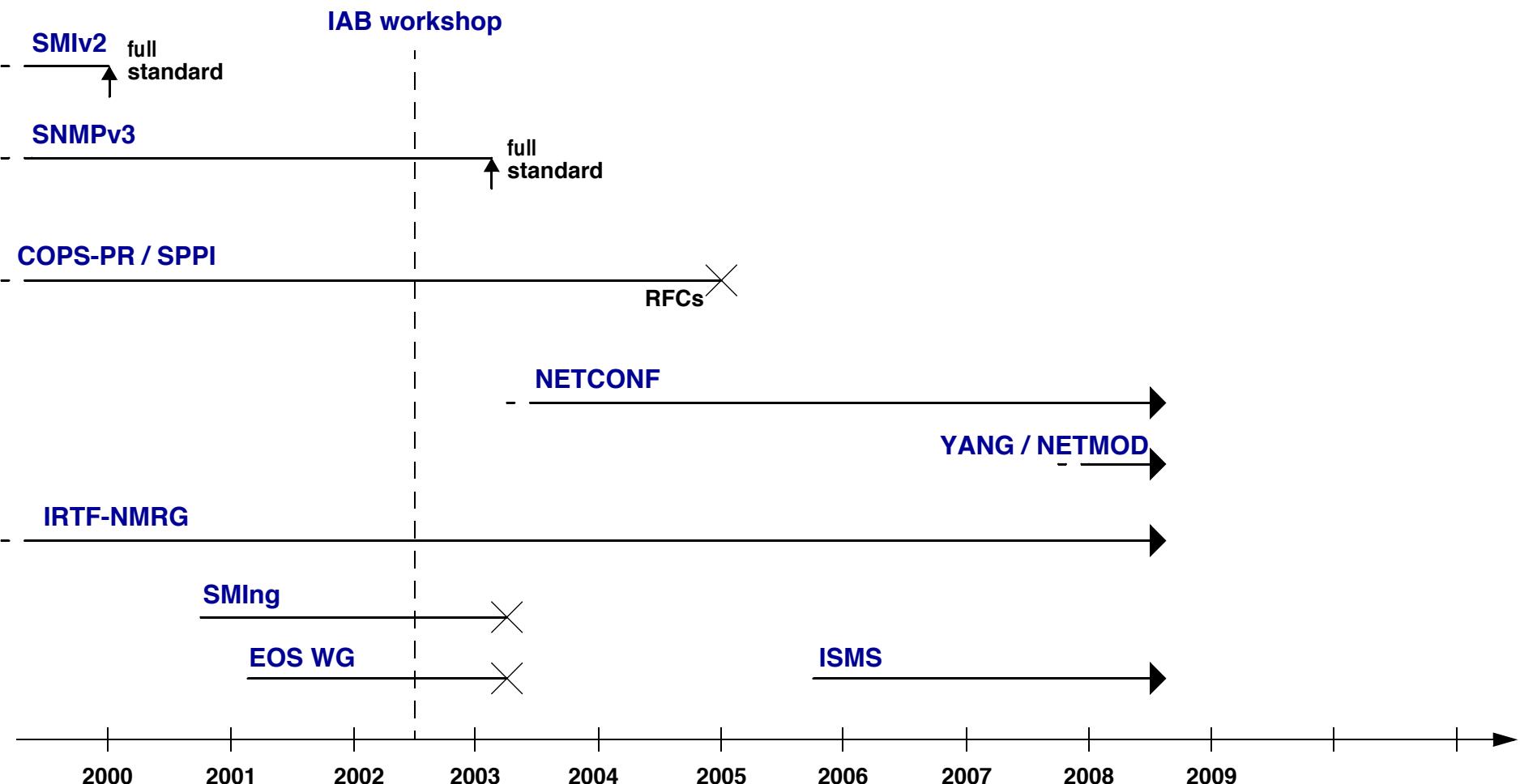
STANDARDS

SMI

- STRUCTURE OF MANAGEMENT INFORMATION
  - SMIv1: RFC 1155 (STANDARD)
 - SMIv2: RFC 2578 (STANDARD)

SNMP

- SNMPv1: RFC 1157 (HISTORIC)
- SNMPv2C: RFC 1901, 1909, 1910 (HISTORIC)
  - SNMPv3: RFC 3411-3416 (STANDARD)

MIBs

- HUNDREDS OF MIB MODULE DEFINITIONS
  - MOST ARE PROPOSED STANDARD
  - SOME ARE DRAFT STANDARD
  - A FEW ARE STANDARD

SNMP STANDARDS

SNMP ENTITY   **RFC 3411**

SNMP APPLICATIONS   **RFC 3413**

SNMP ENGINE

RFC 3412 DISPATCHER	**RFC 3412** MESSAGE PROCESSING SUBSYSTEM	**USM: RFC 3414** SECURITY SUBSYSTEM	**VACM: RFC 3415** ACCESS CONTROL SUBSYSTEM
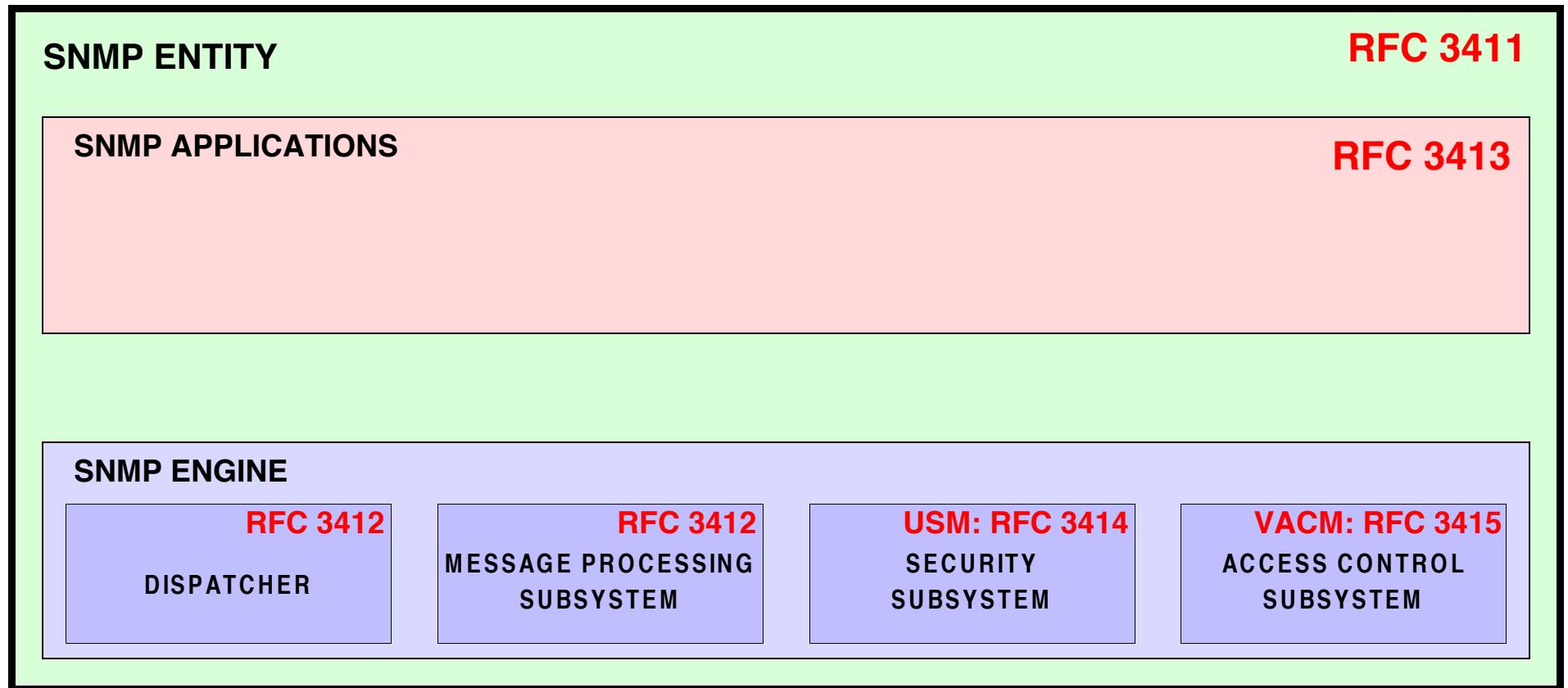
SNMP STANDARDS - CONTINUED

RFC 3416:
- VERSION 2 OF THE SNMP PROTOCOL OPERATIONS
  - FULL STANDARD

RFC 4789:
- SNMP TRANSPORT MAPPINGS
  - FULL STANDARD

SNMP PROTOCOL OPERATIONS

get →

response

manager   agent

set →

response

manager   agent

getNext →

response

manager   agent

← **trap**

manager   agent

getBulk →

response

manager   agent

← **inform**

response →

manager   "agent"

MIB
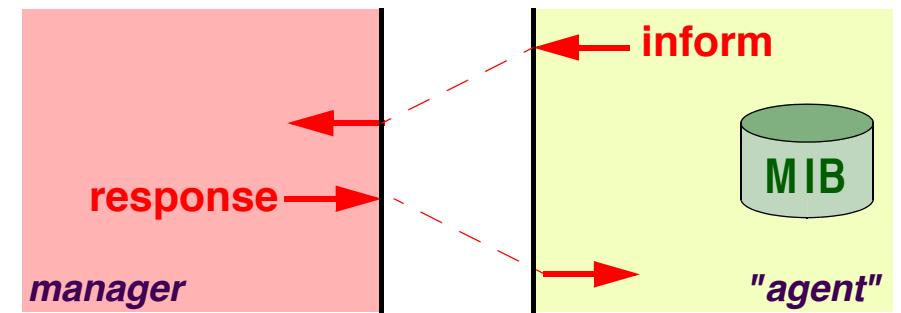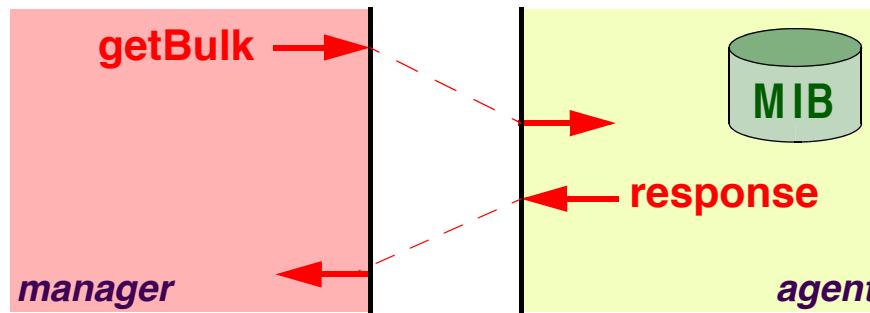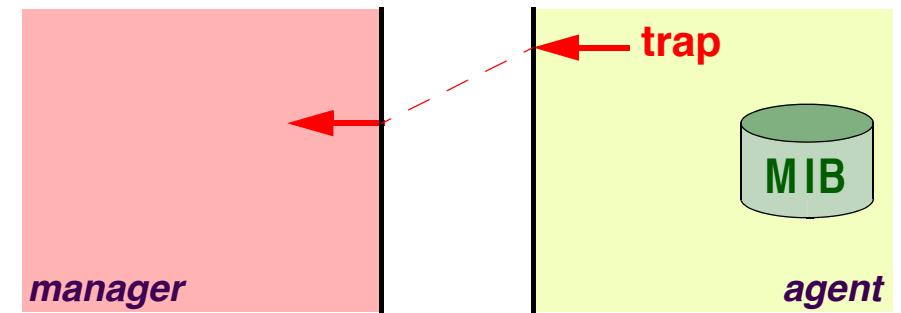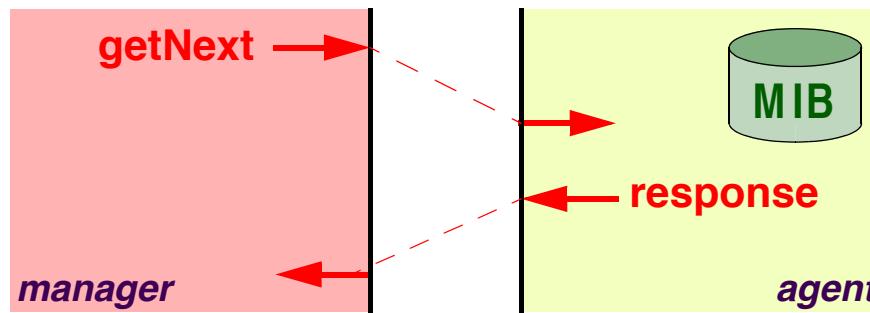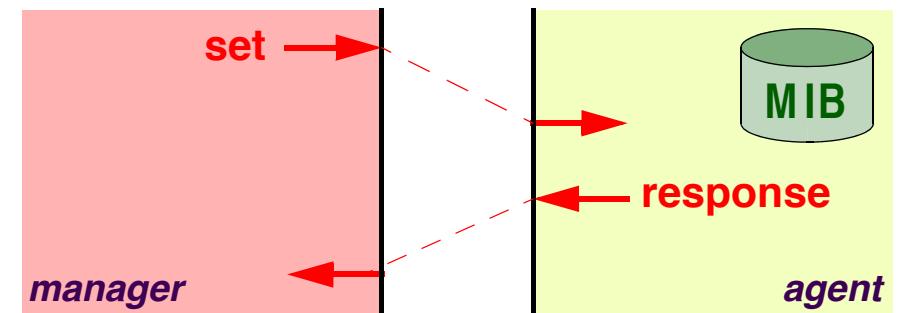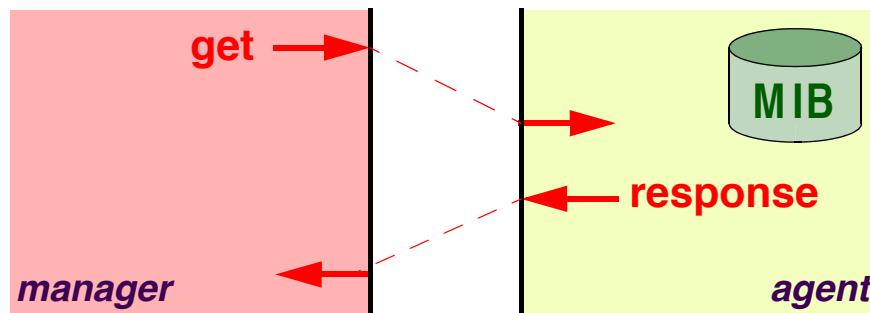
GET
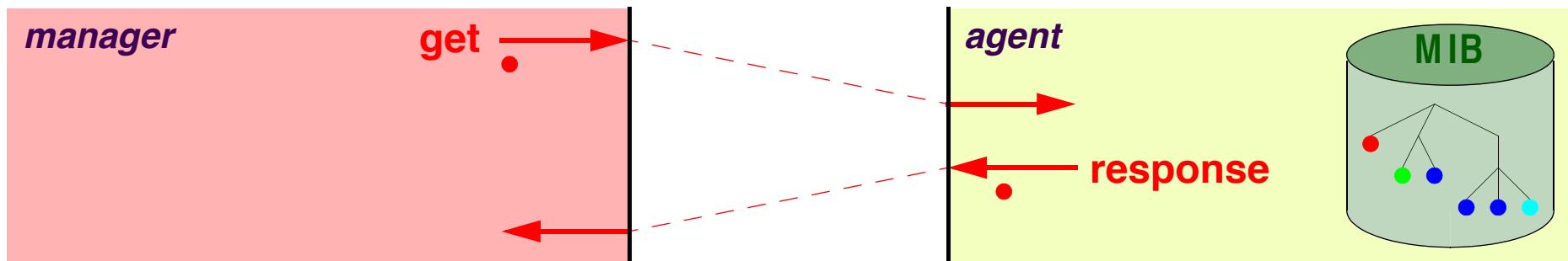
SIMILAR TO SNMPv1, EXCEPT FOR "EXCEPTIONS"

POSSIBLE EXCEPTIONS:
- **noSuchObject**
- **noSuchInstance**

EXCEPTIONS ARE CODED WITHIN THE VARBINDS

EXCEPTIONS DO NOT RAISE ERROR STATUS AND INDEX

GET-NEXT
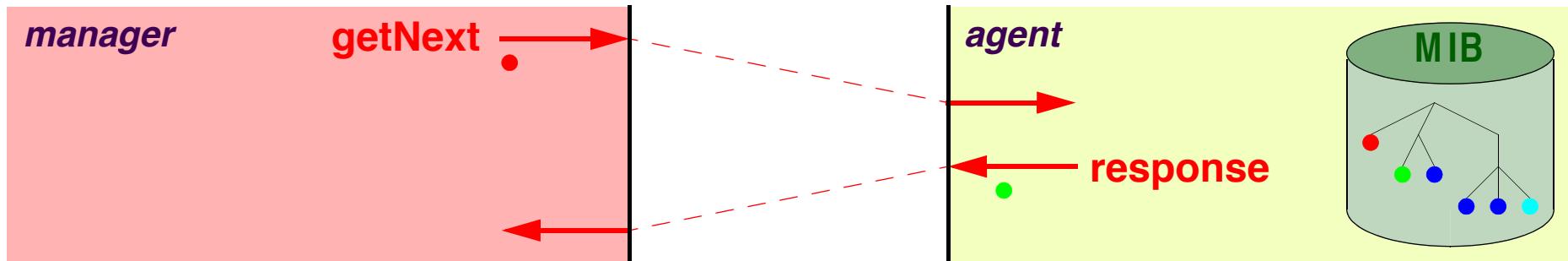
SIMILAR TO SNMPv1, EXCEPT FOR "EXCEPTIONS"

POSSIBLE EXCEPTIONS:
- **endOfMibView**

GET-BULK
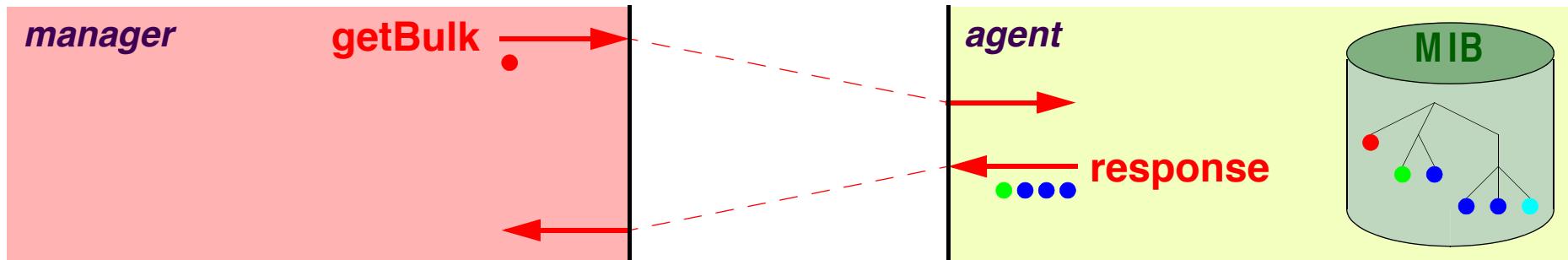
NEW IN SNMPv2

TO RETRIEVE A LARGE NUMBER OF VARBINDS

IMPROVES PERFORMANCE!

GET-BULK

getBulk REQUEST HAS TWO ADDITIONAL PARAMETERS:
- non-repeaters
- max-repetitions

- THE FIRST N ELEMENTS (non-repeaters) OF THE VARBIND LIST
ARE TREATED AS IF THE OPERATION
WAS A NORMAL getnext OPERATION

- THE NEXT ELEMENTS OF THE VARBIND LIST
ARE TREATED AS IF THE OPERATION
CONSISTED OF A NUMBER (max-repetitions)
OF REPEATED getnext OPERATIONS

SET
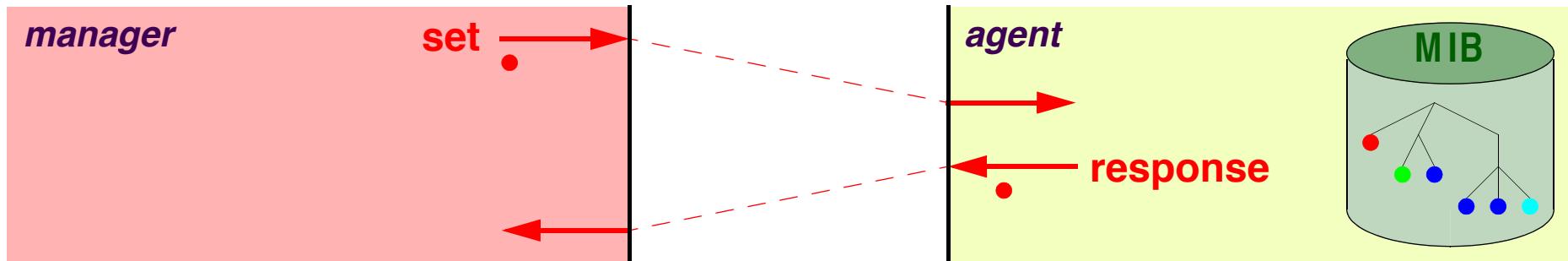
SIMILAR TO SNMPv1

CONCEPTUAL TWO PHASE COMMIT:
- PHASE 1: PERFORM VARIOUS CHECKS
- PHASE 2: PERFORM THE ACTUAL SET

MANY NEW ERROR CODES ARE DEFINED

NEW ERROR CODES FOR SETS

	SNMPv1	SNMPv2
PHASE 1:	badValue	wrongValue
	badValue	wrongEncoding
	badValue	wrongType
	badValue	wrongLength
	badValue	inconsistentValue
	noSuchName	noAccess
	noSuchName	notWritable
	noSuchName	noCreation
	noSuchName	inconsistentName
	genErr	resourceUnavailable
	genErr	genErr
PHASE 2:	genErr	CommitFailed
	genErr	undoFailed

TRAP

manager

agent

MIB
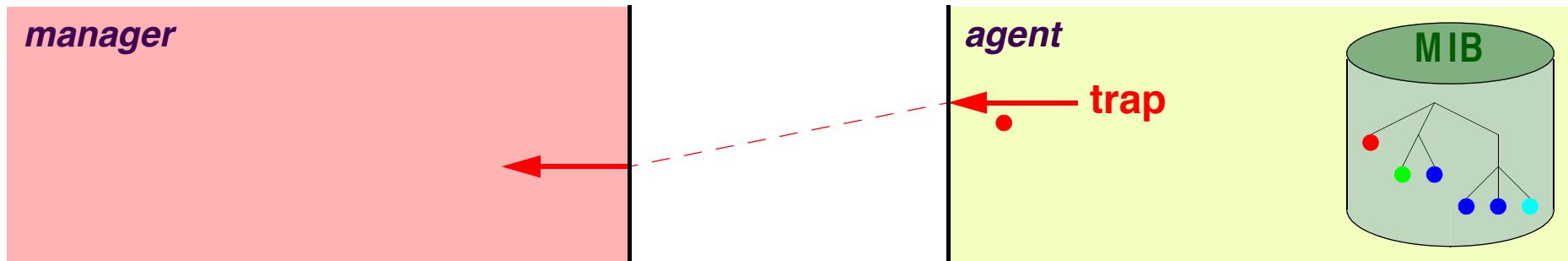
← trap

SNMPv1:
· COLD START
· WARM START
· LINK DOWN
· LINK UP
· AUTHETICATION FAILURE
· EGP NEIGHBOR LOSS

SNMPv2:
· MIBs MAY NOW INCLUDE NOTIFICATION TYPE MACROS
· FIRST TWO VARBINDS: sysUptime AND snmpTrapOID
· USES SAME FORMAT AS OTHER PDUs

EXAMPLE OF NOTIFICATION TYPE MACRO

```
linkUp       NOTIFICATION-TYPE
OBJECTS      {ifIndex}
STATUS       current
DESCRIPTION "A linkUp trap signifies that the entity
             has detected that the ifOperStatus
             object has changed to Up"
::= {snmpTraps 4}
```

INFORM

manager

"agent" **inform**

MIB

Response
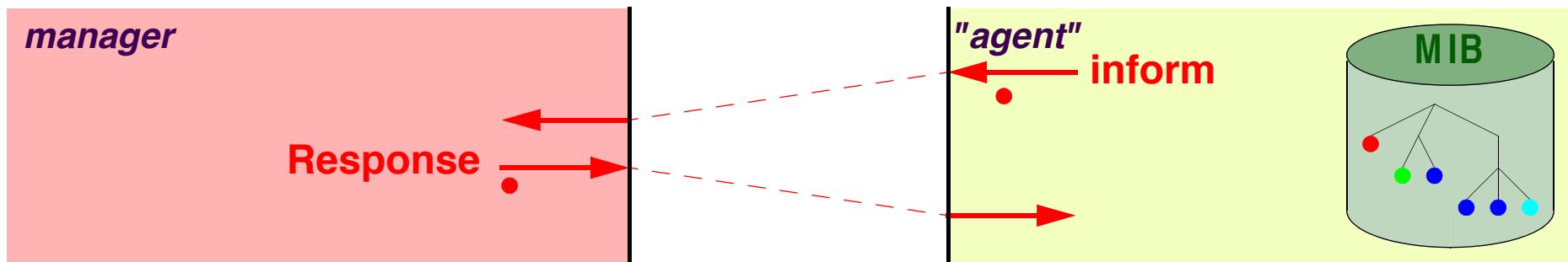
CONFIRMED TRAP

ORIGINALLY TO INFORM A HIGHER LEVEL MANAGER

SAME FORMAT AS TRAP PDU

POSSIBLE ERROR: tooBig

REPORT

manager

agent

← report
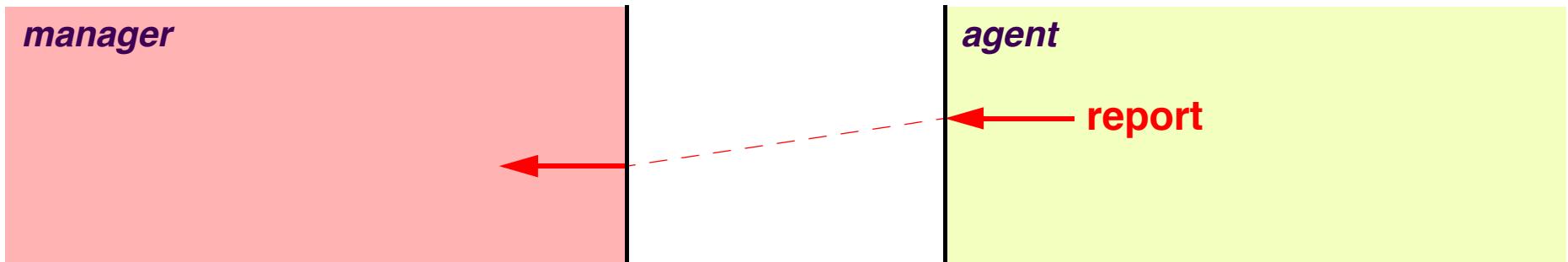
NEW PDU TO SIGNAL PROTOCOL EXCEPTIONS / ERRORS

NO SEMANTICS DEFINED IN SNMPv2

SNMP - SUMMARY

COMPARED TO SNMPv1, IMPROVED COMMUNICATION MODEL
- GET-BULK PDU
- ADDITIONAL ERROR CODES FOR SETS
- INFORMS (CONFIRMED TRAPS)

SECURITY
- SNMPv1 & v2: COMMUNITY BASED (HISTORIC)
- SNMPv3: USER BASED
- NONE, AUTHENTICATION, PRIVACY

MANAGER-AGENT MODEL
- MANAGEMENT HIERARCHIES ARE POSSIBLE (DISMAN)

SNMP PROBLEMS

OVERVIEW:

20 PROBLEMS IDENTIFIED AT THE IAB WORKSHOP

THREE FUNDAMENTAL PROBLEMS

EXAMPLE
· CREATING A NEW TABLE ROW

CAN PROBLEMS BE FIXED?
· COPS-PR

20 PROBLEMS IDENTIFIED AT IAB WORKSHOP - 1

RFC 3535

IMPOSSIBLE TO RETRIEVE COMPLETE CONFIGURATIONS
- IMPOSSIBLE TO COMPARE TO PREVIOUS CONFIGURATIONS
- IMPOSSIBLE TO CHECK FOR CONSISTENCY
- USUALLY INCOMPLETE COVERAGE VIA SNMP
- NO DIFFERENTIATION BETWEEN CONFIGURATION AND STATE DATA

QUALITY OF SNMP IMPLEMENTATIONS SOMETIMES POOR
- DATA NOT ALWAYS CORRECT
- SOMETIMES CRASHES

MIB IMPLEMENTATIONS APPEAR TOO LATE
- OPERATORS HAVE TO RELY ON CLI

OPERATORS VIEW SNMP INTERFACES TOO LOW LEVEL
- TIME CONSUMING AND INCONVENIENT

20 PROBLEMS IDENTIFIED AT IAB WORKSHOP - 2

LEXICOGRAPHIC ORDERING SOMETIMES ARTIFICIAL

- RUNTIME OVERHEAD
- IMPLEMENTATION COSTS

POOR PERFORMANCE OF BULK TRANSFERS

- EXAMPLE: ROUTING TABLES

POOR PERFORMANCE OF CERTAIN QUERIES

- IN CASES DESIGNERS DID NOT ANTICIPATE SUCH QUERIES
- EXAMPLE: WHICH OUTGOING INTERFACE IS USED FOR DESTINATION X?

SNMP CREDENTIALS AND KEY MANAGEMENT COMPLEX

- NOT INTEGRATED WITH EXISTING APPROACHES

SMI

- HARD TO DEAL / NOT VERY PRACTICAL

MIB MODULES OVER-ENGINEERED

- TOO MANY VARIABLES

20 PROBLEMS IDENTIFIED AT IAB WORKSHOP - 3

TRAPS NOT VERY USEFUL
- SUBSEQUENT GETS STILL NEEDED
- SYSLOG MORE USEFUL

SNMP INSTRUMENTATION HARD TO IMPLEMENT
- ESPECIALLY WITH TABLE INDEXING / INTERRELATIONSHIPS

MIB MODULES LACK DESCRIPTION OF POSSIBLE USAGE
- LIST OF INGREDIENTS, WITHOUT RECIPE

NO STRUCTURED TYPES / OBJECT METHODS
- COMPLEX MIB MODULE DESIGN AND IMPLEMENTATION

LACK OF QUERY AND AGGREGATION CAPABILITIES
- NO DATA REDUCTION
- EFFICIENCY AND SCALABILITY PROBLEMS

SNMP PROTOCOL AND AGENT SIMPLICITY
- COMPLEXITY IS LEFT TO THE MANAGER

20 PROBLEMS IDENTIFIED AT IAB WORKSHOP - 4

SEMANTIC MISMATCH
- MIB IS LOW-LEVEL, DATA ORIENTED
- MANAGERS THINK TASK ORIENTED
- BRIDGING THE GAP IS POSSIBLE, BUT HARD

NOT WELL SUITED FOR COMPLEX DEVICES
- SNMP WORKS WELL FOR SMALL DEVICES

NO INCENTIVE FOR VENDORS TO IMPLEMENT SNMP MIBS
- CLI GETS PRECEDENCE
- NOT ALL CLI COMMANDS ARE AVAILABLE VIA MIB MODULES
- UNDERMINES THIRD PARTY STANDARD SOLUTIONS

STANDARDS FREEZE DEVELOPMENT
- RAPID FEATURE DEVELOPMENT NOT POSSIBLE

FUNDAMENTAL PROBLEM - 1

IF EVERYTHING FAILS, MANAGEMENT SHOULD STILL FUNCTION

NO USE OF EXISTING SECURITY MECHANISMS

- CREDENTIAL AND KEY MAINTENANCE IS HARD

FUNDAMENTAL PROBLEM - 2

USE OF UDP

MESSAGES ARE LIMITED IN SIZE

· OBJECTS ARE THEREFORE SMALL (SCALARS)

· GRANULARITY LEVEL TOO LOW FOR CONFIGURATION MANAGEMENT

· NO COMPLEX DATA STRUCTURES

UNRELIABLE COMMUNICATION

· RETRANSMISSION BY APPLICATION

FUNDAMENTAL PROBLEM - 3

MULTIPLE MANAGERS MAY OPERATE CONCURRENTLY

SYNCHRONIZATION IS HARD

- **RowStatus**

- **snmpSerialNo**

EXAMPLE

1) SELECT / CREATE INDEX

2) SET RowStatus OBJECT TO *createAndWait*

INDEX	COLUMN 1	COLUMN ...	COLUMN N	RowStatus

3) SET COLUMN FIELDS
POSSIBLY INCLUDE IN EVERY SET PDU snmpSerialNo

4) SET RowStatus OBJECT TO *active*

IN CASE OF ERRORS
RESTORING A PREVIOUS STATE MAY BE DIFFICULT

HOW TO FIX THE PROBLEMS

EVOLUTIONARY

IRTF
- NETWORK MANAGEMENT RESEARCH GROUP (NMRG)
- SNMP OVER TCP
- EFFICIENT RETRIEVAL OF BULK DATA
- IMPROVED SMI

IETF
- EVOLUTION OF SNMP (EOS) WG
- SMI NEXT GENERATION (SMIng) WG
- COMMON OPEN POLICY SERVICES PROTOCOL - POLICY PROVISIONING WG

REVOLUTIONARY

IETF
NETWORK CONFIGURATION (NETCONF) WG
- XML BASED

RESEARCH COMMUNITY
- WEB-SEVICES BASED

COPS-PR

COMMON OPEN POLICY SERVICES PROTOCOL - POLICY PROVISIONING

POLICY INFORMATION BASE

**STRUCTURE OF POLICY PROVISIONING INFORMATION
SPPI**
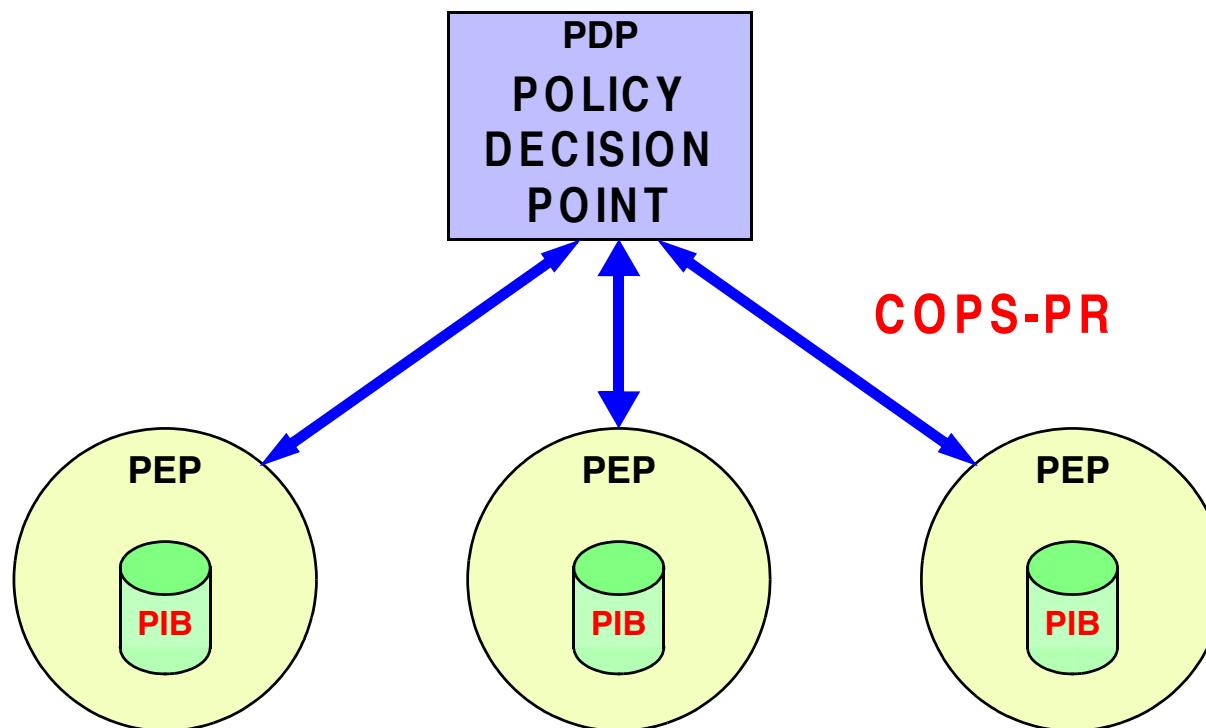
COPS-PR

- INTENDED FOR CONFIGURATION MANAGEMENT

- TECHNOLOGY COMPARIBLE TO SNMP

- OBJECTS HAVE HIGHER GRANULARITY (TABLE ROWS)

- SINGLE OPERATION TO ADD OR DELETE TABLE ROWS

- RELIABLE COMMUNICATION BETWEEN PDP AND PEP (BECAUSE OF TCP)

- EACH PEP IS CONNECTED TO SINGLE PDP

NETCONF BACKGROUND

IAB NETWORK MANAGEMENT WORKSHOP (JUNE 2002):

- SNMP IS USED FOR MONITORING

- SNMP IS HARDLY USED FOR CONFIGURATION MANAGEMENT

- OPERATORS DO NOT WANT TO CONFIGURE SMALL OBJECTS

- OPERATORS WANT TO OPERATE ON COMPLETE "CONFIGURATIONS"

- FOR CONFIGURATION MANAGEMENT, OPERATORS STILL RELY ON CLI

- CLI SCRIPTS ARE HARD TO WRITE / MAINTAIN, HOWEVER

- APPROACHES LIKE JUNOSCRIPT ARE MORE ATTRACTIVE

OPERATOR'S CONFIGURATION MANAGEMENT MODEL
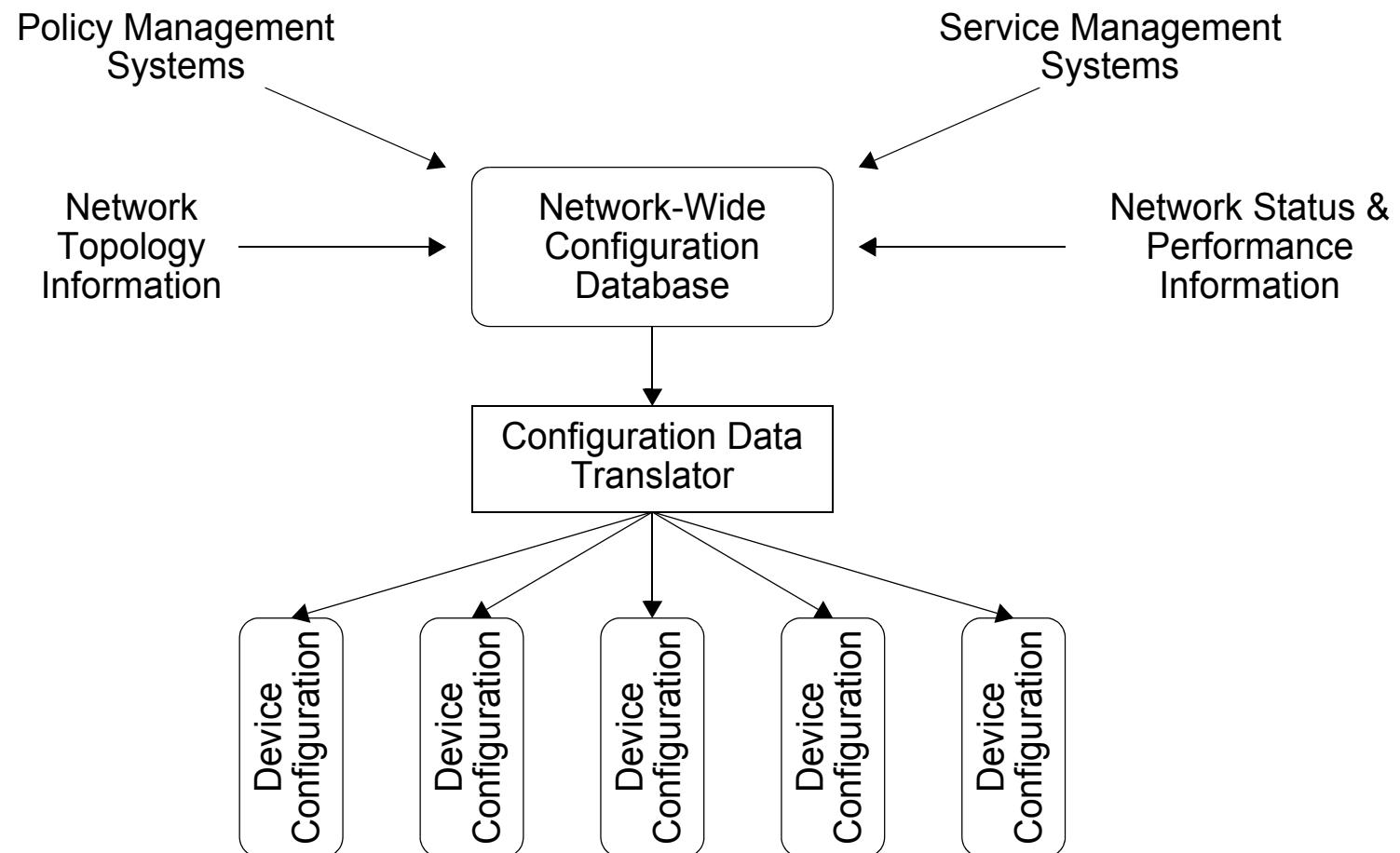
JUNOSCRIPT API

INTRODUCED 2001

XML ENCODED RPC CALLS

RUNS OVER SSH OR TELNET

RESPONSES CAN BE FILTERED USING COMMON TOOLS LIKE XPATH

RESPONSES CAN BE DISPLAYED USING COMMON TOOLS LIKE XSLT / CCS

JUNIPER "INTEGRATED" CLI & XML INTERFACE
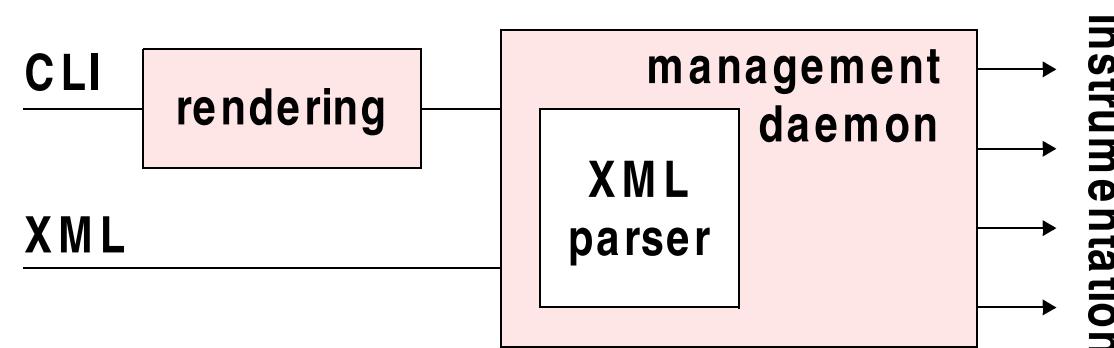
JUNOSCRIPT RPC CALL - EXAMPLE

```
<rpc>
   <get-interface-information>
      <statistics/>
   </get-interface-information>
</rpc>

<rpc-reply>
  <interface-information>
      <InOctets>123456</InOctets>
      <InErrors>789</InErrors>
      <OutOctets>654321</OutOctets>
      <OutErrors>0</OutErrors>
  </interface-information>
</rpc-reply>
```

1

NETCONF CHARTER

- SOLUTIONS FOR CONFIGURATION MANAGEMENT

- PROGRAMMATIC INTERFACE

- TEXTUAL DATA REPRESENTATION

- BASED ON XML TECHNOLOGY

- INTEGRATES WITH EXISTING USER AUTHENTICATION METHODS

- INTEGRATES WITH EXISTING CONFIGURATION DATABASE SYSTEMS

- SUPPORTS NETWORK WIDE CONFIGURATION TRANSACTIONS
  LOCKING IS MANDATORY
  ROLL-BACK IS OPTIONAL

- INDEPENDENT OF A DATA DEFINITION LANGUAGE
  AGREEMENT ON SUCH LANGUAGE MAY NOT HAVE BEEN EASY
  2007: YANG / 2008 NETMOD

FEATURES

- OPERATES ON DOCUMENTS, INSTEAD OF OBJECTS
  GRANULARITY LEVEL IS THEREFORE HIGH

- OPERATIONS TO RETRIEVE AND PATCH CONFIGURATIONS

- MULTIPLE CONFIGURATIONS MAY EXIST

- SECURITY IS PROVIDED AT LOWER LAYERS
  USE OF TCP / SSH
  USE OF EXISTING SECURITY MECHANISMS

NETCONF LAYERED MODEL

LAYERS		EXAMPLE
CONTENT		XML CONFIGURATION DATA
OPERATIONS		<get-config>, <edit-config>
RPC		<rpc>, <rpc-reply>
TRANSPORT		SSH*, HTTPS, BEEP

CONFIGURATION DATA:

\<RUNNING\> CONFIGURATION
- IS MANDATORY

\<STARTUP\> CONFIGURATION

\<CANDIDATE\> CONFIGURATION

NETCONF OPERATIONS

- GET-CONFIG (SOURCE, FILTER)

- EDIT-CONFIG(TARGET, OPTIONS, CONFIG)

- COPY-CONFIG(SOURCE, TARGET)

- DELETE-CONFIG(TARGET)

- GET(FILTER)

- VALIDATE(SOURCE)

- LOCK(SOURCE)

- UNLOCK(SOURCE)

- COMMIT(CONFIRMED, CONFIRMED-TIMEOUT)

WEB SERVICES FOR MANAGEMENT

WHY WEB SERVICES?

WHAT ARE WEB SERVICES?

EXAMPLE & PERFORMANCE

TOOLS

CONCLUSIONS

WHY WEB SERVICES?

EVOLUTION OF SNMP FAILED

NEW TECHNOLOGIES ARE NEEDED

WEB SERVICES MAY BECOME THE MOST IMPORTANT
MIDDLEWARE TECHNOLOGY

WILL BECOME AVAILABLE ON ALL FUTURE PLATFORMS

WILL BE APPLIED FOR MANY KINDS OF APPLICATIONS

IMPLEMENTATION OF WS APPLICATIONS IS RELATIVELY SIMPLE

MANY SKILLED DEVELOPERS

MANY TOOLS

FUTURE MANAGEMENT EXPERTS
CAN CONCENTRATE ON MANAGEMENT APPLICATIONS
INSTEAD OF MANAGEMENT TECHNOLOGY

WHY WEB SERVICES?

SOME FACTS

MANY PROGRAMMING LANGUAGES HAVE WS LIBRARIES

PART OF DEVELOPMENT PLATFORMS: .NET, SUN-ONE, JBUILDER

WS SUPPORT INCLUDED IN WINDOWS / OFFICE

CALLING A WS FROM EXCEL TAKES 4 LINES OF CODE

COMPARE THIS TO SNMP!

THE KEY TO SUCCESS WILL BE EASE OF USE!

WHY WEB SERVICES?

THE HYPE

IRTF-NMRG
Network Management Research Group

OASIS
Web Services Distributed Management

OGSI
Open Grid Services Infrastructure Working Group

PARLAY GROUP
Parley-X

MANY RESEARCH GROUPS

OVERVIEW

WHY WEB SERVICES?

WHAT ARE WEB SERVICES?

EXAMPLE & PERFORMANCE

TOOLS

CONCLUSIONS

WHAT ARE WEB SERVICES?

WEB SERVICES COMPONENTS

PROTOCOL STACK

MAIN W3C SPECIFICATIONS

STRUCTURE WSDL DEFINITION

OPERATION STRUCTURE

DATA TYPES

ADVANCED FEATURES
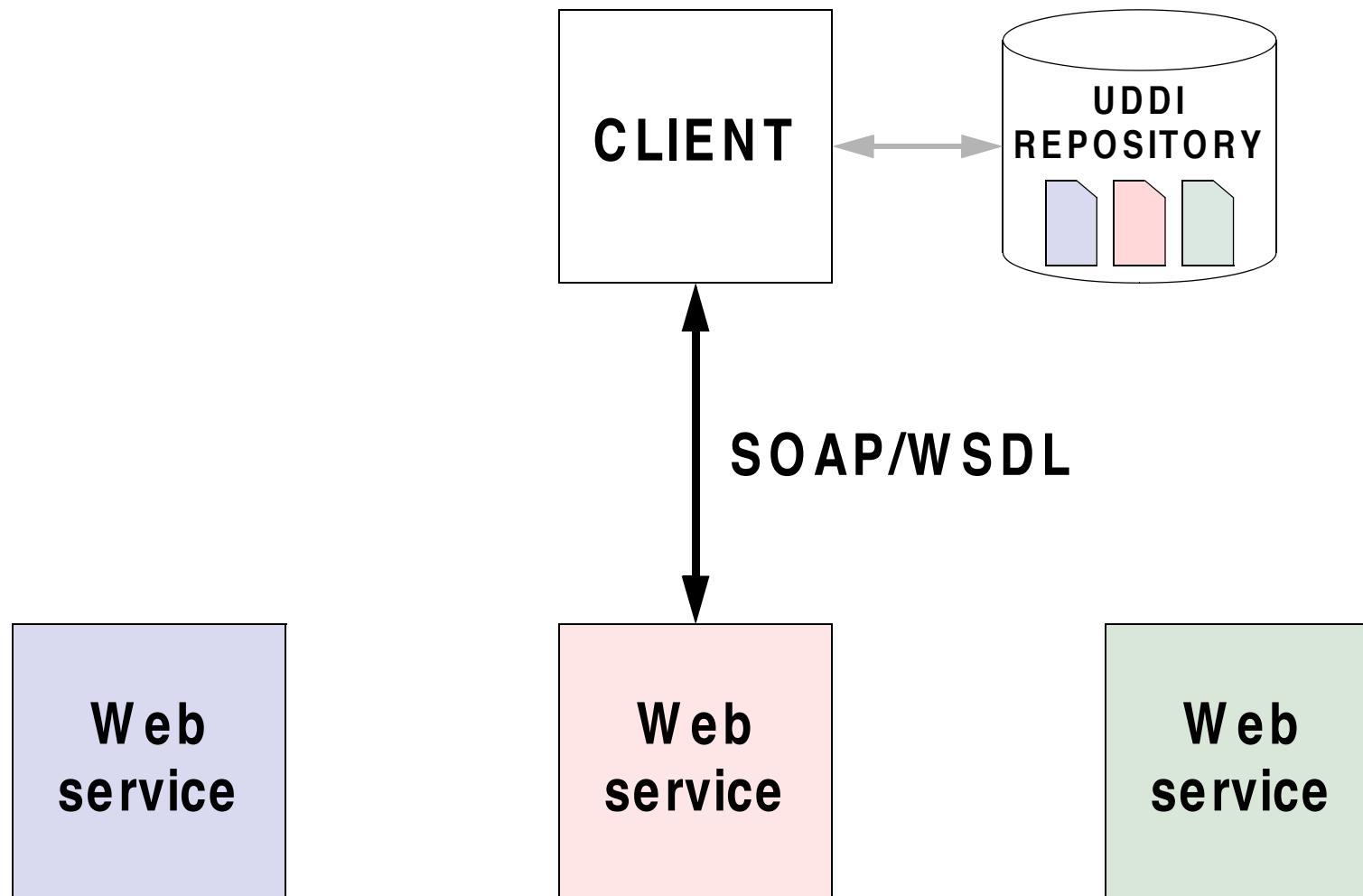
WEB SERVICES COMPONENTS FOR MANAGEMENT

STACK DIAGRAM

Processes

Discovery, Aggregation, Choreography ...

Descriptions

Web Services Descriptions (WSDL)

Messages

SOAP Extensions
Reliability, Correlation, Transactions, ...

SOAP

Base Technologies: XML, Schema, ...

Base Technologies: XML, Schema, ...

Communications

HTTP, SMTP, FTP, ...
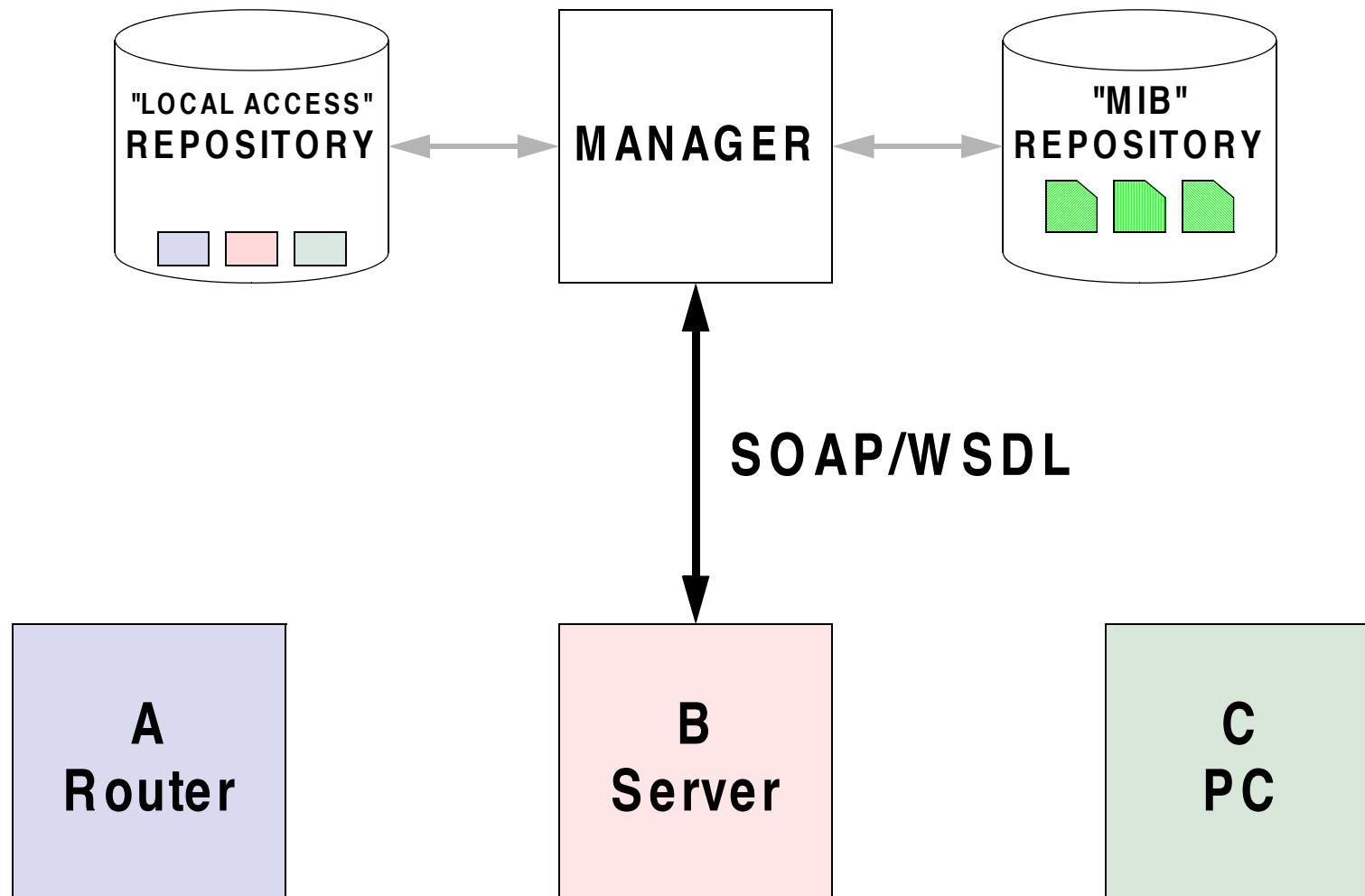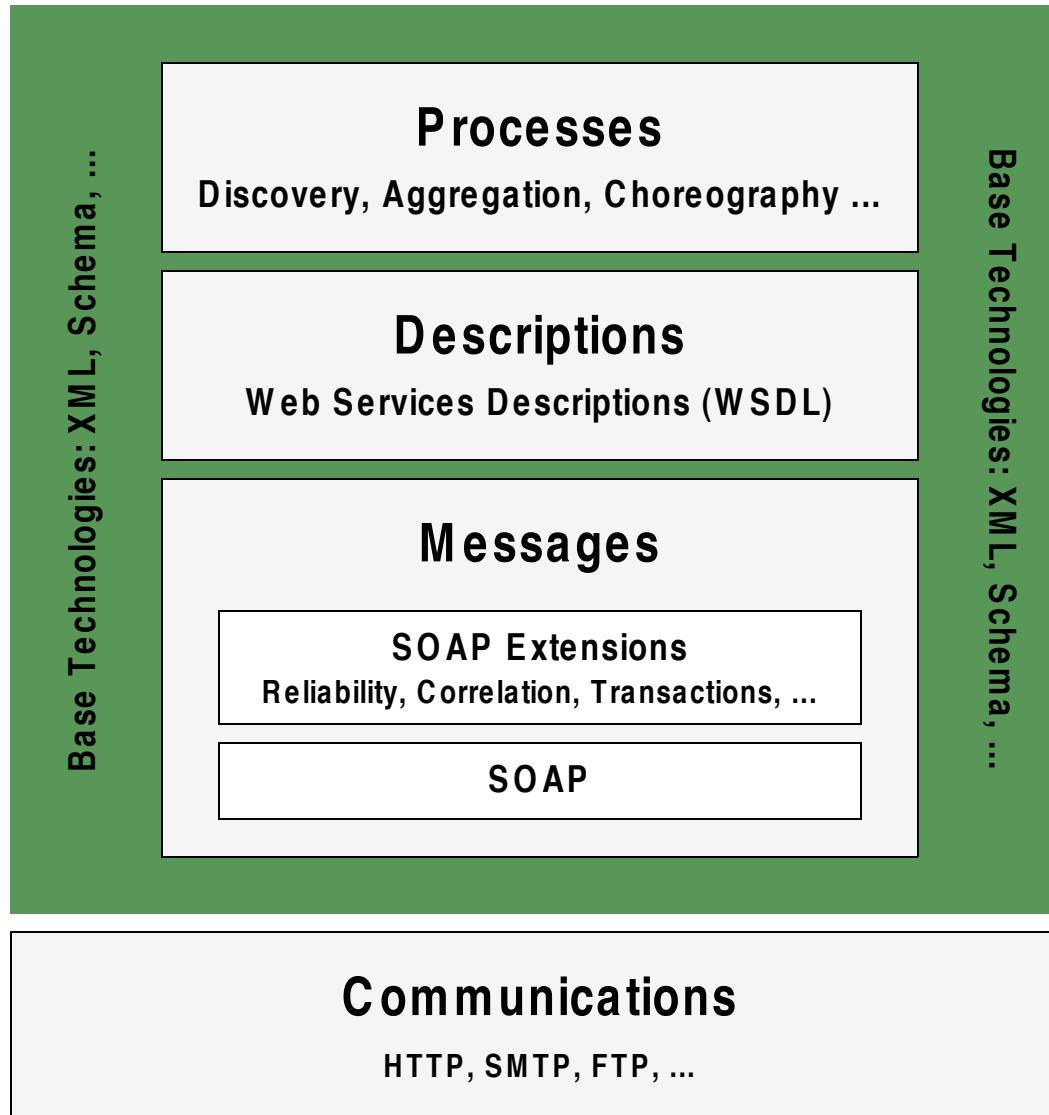
MAIN W3C DOCUMENTS

Web Services Description Language (WSDL)

W3C Recommendation - Version 2.0 - 2007
- **Part 0: Primer**
- **Part 1: Core Language**
- **Part 2: Adjuncts**

SOAP

Version 1.2 - W3C Recommendation - 2007
- **Part 0: Primer**
- **Part 1: Messaging Framework**
- **Part 2: Adjuncts**

XML Schema

W3C Recommendation - 2004
- **Part 0: Primer**
- **Part 1: Structures**
- **Part 2: Datatypes**

STRUCTURE WSDL DEFINITION

ABSTRACT INTERFACE TO THE WEB SERVICE

**Independent of a specific
transport protocol
and Web address**

BINDING

**To associate the abstract interface
with a transport protocol**

SERVICE

**To associate the abstract interface
with a Web address**

STRUCTURE WSDL DEFINITION
ABSTRACT INTERFACE - EXAMPLE

```
<message name="getIfInOctetsRequest">
    <part name="community" type="xsd:string"/>
    <part name="index" type="xsd:unsignedInt"/>
</message>

<message name="getIfInOctetsResponse">
    <part name="ifInOctets" type="xsd:unsignedInt"/>
</message>


<interface name="IfDataServiceInterface">
    <operation name="getIfInOctets">
        <input message="myns:getIfInOctetsRequest"/>
        <output message="myns:getIfInOctetsResponse"/>
    </operation>
</interface>
```

STRUCTURE WSDL DEFINITION
BINDING TO A PROTOCOL - EXAMPLE

```xml
<binding name="ifDataServiceBinding"
        interface="myns:IfDataServiceInterface">

    <soap:binding style="rpc" transport="http://schemas.xmlsoap.org/soap/http"/>

    <operation  name="getIfInOctets">
        <soap:operation soapAction=""/>
        <input>
            <soap:body use="encoded" namespace="urn:..."
                encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"/>
        </input>

        <output>
            <soap:body use="encoded" namespace="urn:..."
                encodingStyle="http://schemas.xmlsoap.org/soap/encoding/"/>
        </output>

    <operation>
</binding>
```

STRUCTURE WSDL DEFINITION
SERVICE AT A WEB ADDRESS - EXAMPLE

```
<service name="ifDataService" interface="myns:IfDataServiceInterface">

    <endpoint name="ifDataServiceEndpoint"
              binding="myns:ifDataServiceBinding"
        <soap:address location="http://my.webservice.com/ifData/"/>
    </endpoint>

</service>
```

MODULAR WSDL STRUCTURE

**ABSTRACT
INTERFACES**

IF MODULE

<message ...
<operation ...
   getIfTable

IP MODULE

<message ...
<operation ...
   getRouteTable

IF BINDING

<import IF MODULE
<binding ...
   SOAP

IP BINDING

<import IP MODULE
<binding ...
   SOAP

STANDARDIZED

SITE SPECIFIC

MY MGT. SERVICE

<import IF BINDING
<import IP BINDING

<service
   http://...
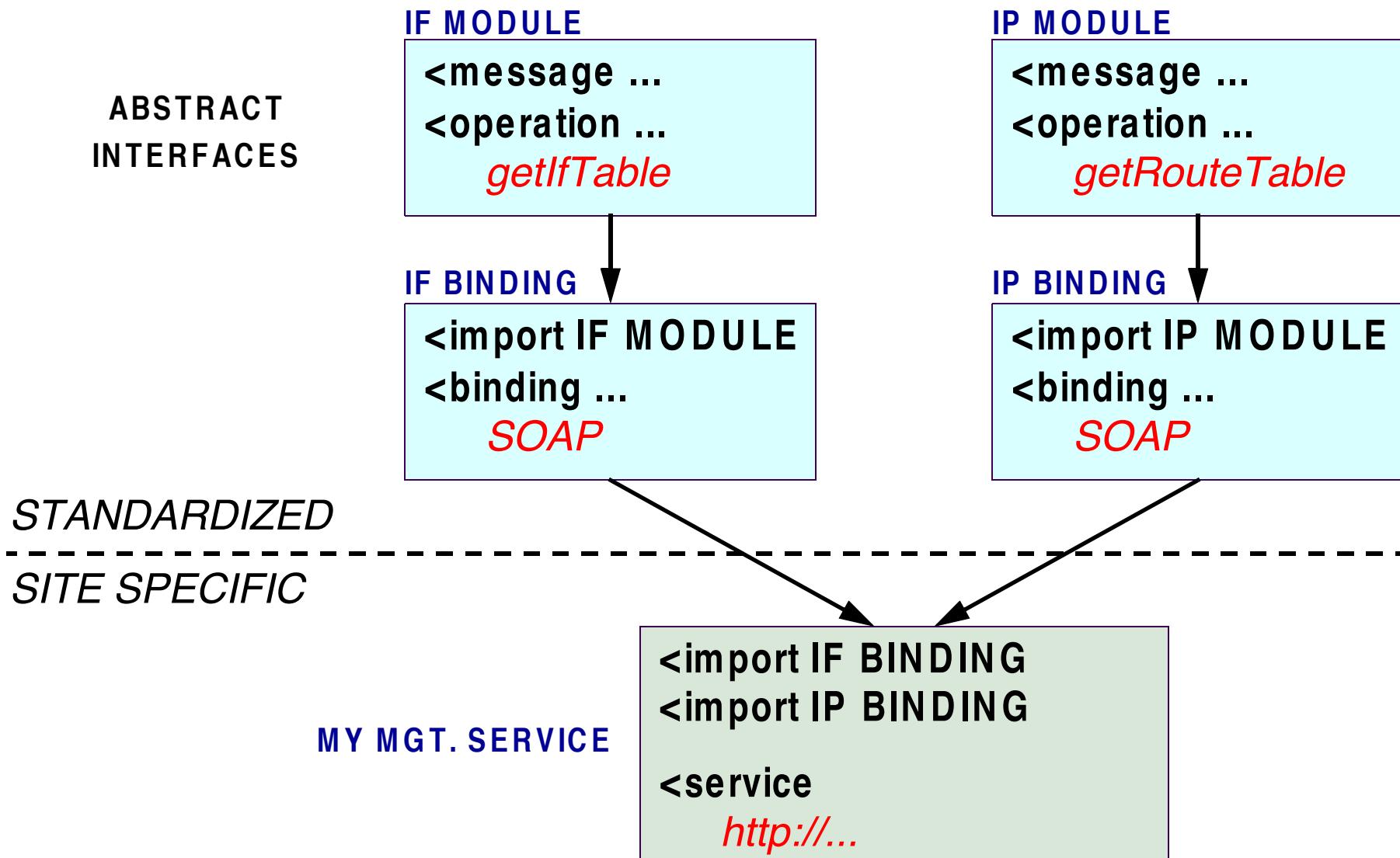
POSSIBLE MESSAGE STRUCTURE

COARSE

- get(OID, instance, ...)
- set (OID, instance, ...)
- ...
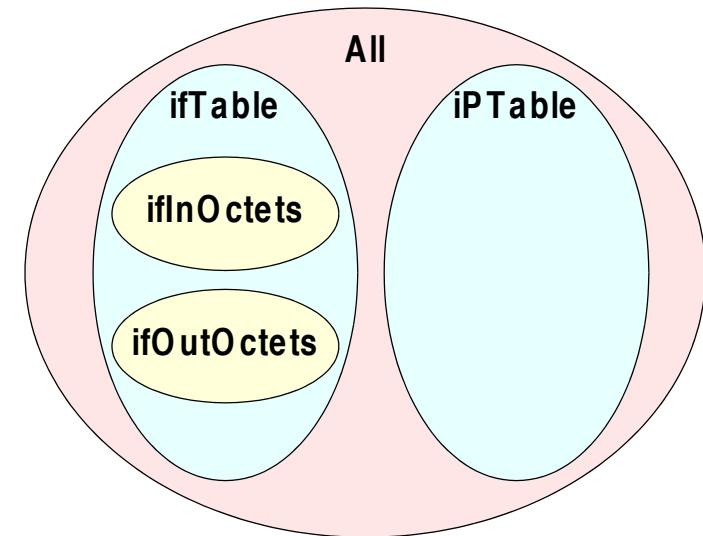
FINE

- getAll(...)
- getIfTable(...)
- getIfInOctets(index, ...)
- getIfOutOctets(index, ...)
- ...
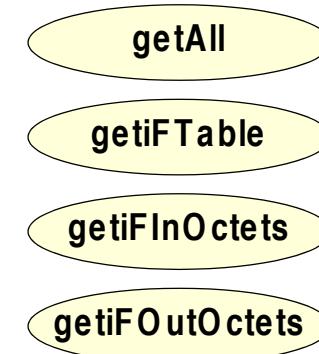
POSSIBLE MESSAGE PARAMETERS

NON-TRANSPARENT
getIfInOctets(index, amount)
- Data parsed at WSDL level
- One level of standards: WSDL
- Less flexible
- Easy integration with standard applications
- Simple users (home environments)

TRANSPARENT
getIfInOctets(string)
- Data parsed by higher level application
- Data could be XML encoded
- Two levels of standards: WSDL operation & XML data
- Powerful (e.g. XPATH / XQUERY)
- Harder to use (professional operators)

DATA TYPES

```
                                  ┌──────────┐
                                  │ anyType  │
                                  └──────────┘
          ┌···········································┐
  ┌─────────────────┐              ┌──────────────┐
  │all complex types│              │anySimpleType │
  └─────────────────┘              └──────────────┘

  ┌──────────┐ ┌──────────┐ ┌──────┐ ┌──────┐ ┌────────────┐ ┌───────┐ ┌───────────┐ ┌──────┐ ┌────────┐
  │ duration │ │ dateTime │ │ time │ │ date │ │ gYearMonth │ │ gYear │ │ gMonthDay │ │ gDay │ │ gMonth │
  └──────────┘ └──────────┘ └──────┘ └──────┘ └────────────┘ └───────┘ └───────────┘ └──────┘ └────────┘

  ┌─────────┐ ┌──────────────┐ ┌───────────┐ ┌───────┐ ┌────────┐   ┌────────┐ ┌────────┐ ┌──────────┐
  │ boolean │ │ base64Binary │ │ hexBinary │ │ float │ │ double │   │ anyURI │ │ QName  │ │ NOTATION │
  └─────────┘ └──────────────┘ └───────────┘ └───────┘ └────────┘   └────────┘ └────────┘ └──────────┘

  ┌────────┐                                              ┌─────────┐
  │ string │                                              │ decimal │
  └────────┘                                              └─────────┘

  ┌──────────────────┐                                    ┌─────────┐
  │ normalizedString │                                    │ integer │
  └──────────────────┘                                    └─────────┘

  ┌───────┐                          ┌───────────────────┐ ┌──────┐ ┌───────────────────┐
  │ token │                          │ nonPositiveInteger│ │ long │ │ nonNegativeInteger│
  └───────┘                          └───────────────────┘ └──────┘ └───────────────────┘

  ┌──────────┐ ┌──────┐ ┌─────────┐ ┌─────────────────┐ ┌─────┐ ┌──────────────┐ ┌─────────────────┐
  │ language │ │ Name │ │ NMTOKEN │ │ negativeInteger │ │ int │ │ unsignedLong │ │ positiveInteger │
  └──────────┘ └──────┘ └─────────┘ └─────────────────┘ └─────┘ └──────────────┘ └─────────────────┘

              ┌────────┐ ┌──────────┐                    ┌───────┐ ┌─────────────┐
              │ NCName │ │ NMTOKENS │                    │ short │ │ unsignedInt │
              └────────┘ └──────────┘                    └───────┘ └─────────────┘

          ┌────┐ ┌───────┐ ┌────────┐                    ┌──────┐ ┌───────────────┐
          │ ID │ │ IDREF │ │ ENTITY │                    │ byte │ │ unsignedShort │
          └────┘ └───────┘ └────────┘                    └──────┘ └───────────────┘

                 ┌────────┐ ┌──────────┐                          ┌──────────────┐
                 │ IDREFS │ │ ENTITIES │                          │ unsignedByte │
                 └────────┘ └──────────┘                          └──────────────┘
```

ADVANCED FEATURES

TRANSACTIONS
- Business Transaction Protocol (OASIS)
- WS-Coordination + WS-Transaction (BEA, IBM, MS)
- WS-Composite Application Framework (Arjuna, Fujitsu, IONA, Oracle, Sun)

SECURITY
- WS-Security (IBM, OASIS)

CHOREOGRAPHY / ORCHESTRATION
- XLANG (MS), WSFL (IBM)
- BPEL4WS (IBM, MS, BEA)
- WSCI (SUN, ...)
- W3C

OVERVIEW

WHY WEB SERVICES?

WHAT ARE WEB SERVICES?

EXAMPLE & PERFORMANCE

TOOLS

CONCLUSIONS

<u>EXAMPLE</u>

PROTOTYPE

· **ifTable**
GetIfCell
GetIfColumn
GetIfRow
GetIfTable

· **gSOAP (2.3.8)**

· **Net-SNMP (V5.0.x) Data retrieval functions**

· **Debian Linux, kernel v2.4.22, 800 Mhz Pentium**

EXAMPLE

```
<complexType name="GetIfTableResponse">
  <sequence>
    <element name="ifEntry" type="utMon:ifEntry" minOccurs="1" maxOccurs="unbounded"/>
  </sequence>
 </complexType>


<message name="GetIfTableRequest">
  <part name="commuity" type="xsd:string"/>
</message>


<message name="GetIfTableResponse">
  <part name="sizeTable" type="xsd:int"/>
  <part name="ifEntry" type="utMon:ifEntry"/>
</message>


<portType name="GetIfTableServicePortType">
 <operation name="GetIfTable">
  <documentation>Service definition of function utMon__GetIfTable</documentation>
  <input message="tns:GetIfTableRequest"/>
  <output message="tns:GetIfTableResponse"/>
 </operation>
</portType>
```

EXAMPLE

```
<complexType name="ifEntry">
  <sequence>
  <element name="ifIndex" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifDescr" type="xsd:string" minOccurs="1" maxOccurs="1" nillable="true"/>
  <element name="ifType" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifMtu" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifSpeed" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifPhysAddress" type="xsd:string" minOccurs="1" maxOccurs="1" nillable="true"/>
  <element name="ifAdminStatus" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifOperStatus" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifLastChange" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifInOctets" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifInUcastPkts" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifInDiscards" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifInErrors" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifInUnknownProtos" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifOutOctets" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifOutUcastPkts" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  <element name="ifOutErrors" type="xsd:unsignedInt" minOccurs="1" maxOccurs="1"/>
  </sequence>
</complexType>
```

OVERVIEW

WHY WEB SERVICES?

WHAT ARE WEB SERVICES?

EXAMPLE

PERFORMANCE

TOOLS

CONCLUSIONS

PERFORMANCE - BANDWIDTH
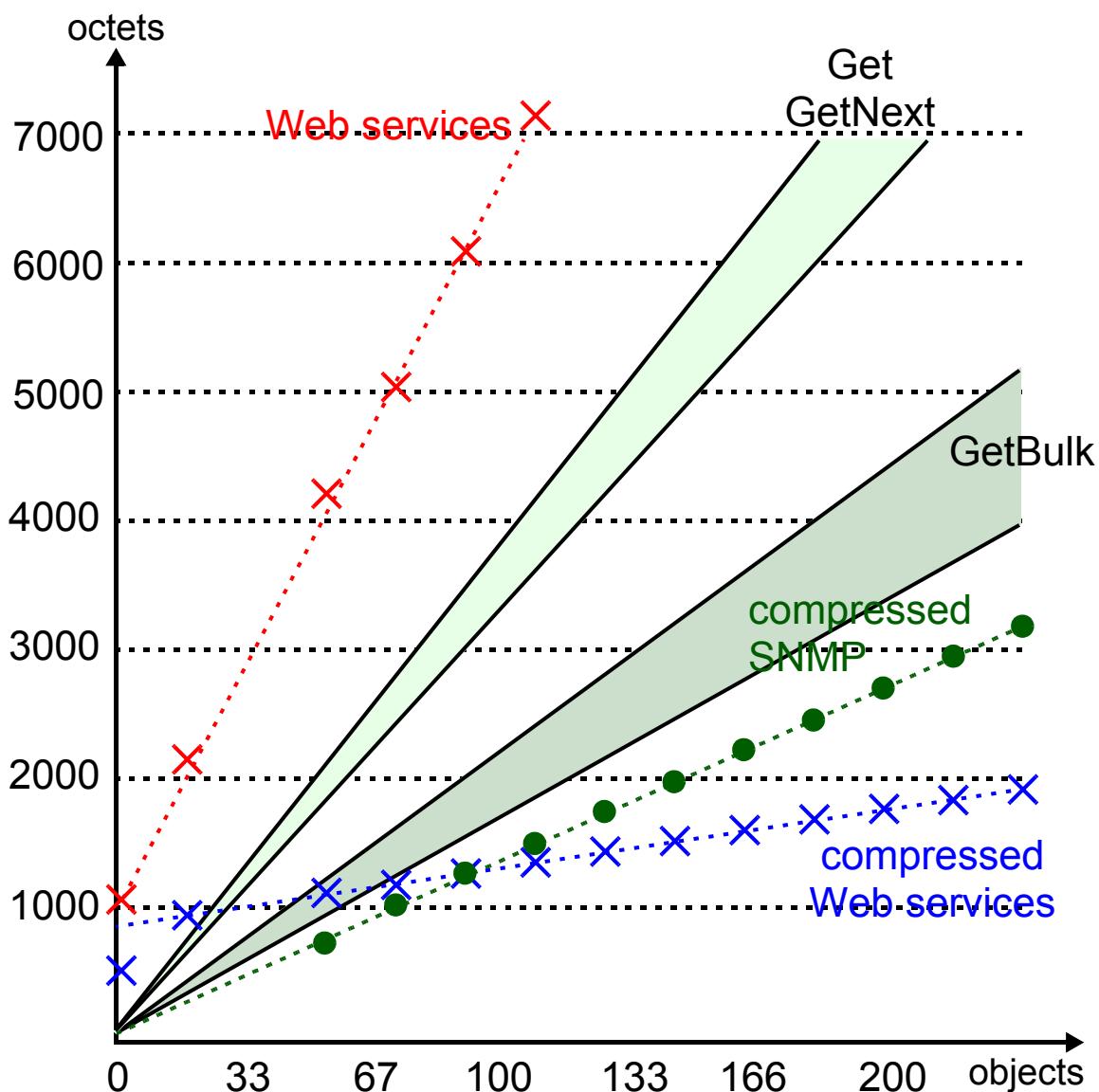
PERFORMANCE - CPU TIME - CODING & COMPRESSION

time (ms)

WS compression

XML coding

BER coding

objects
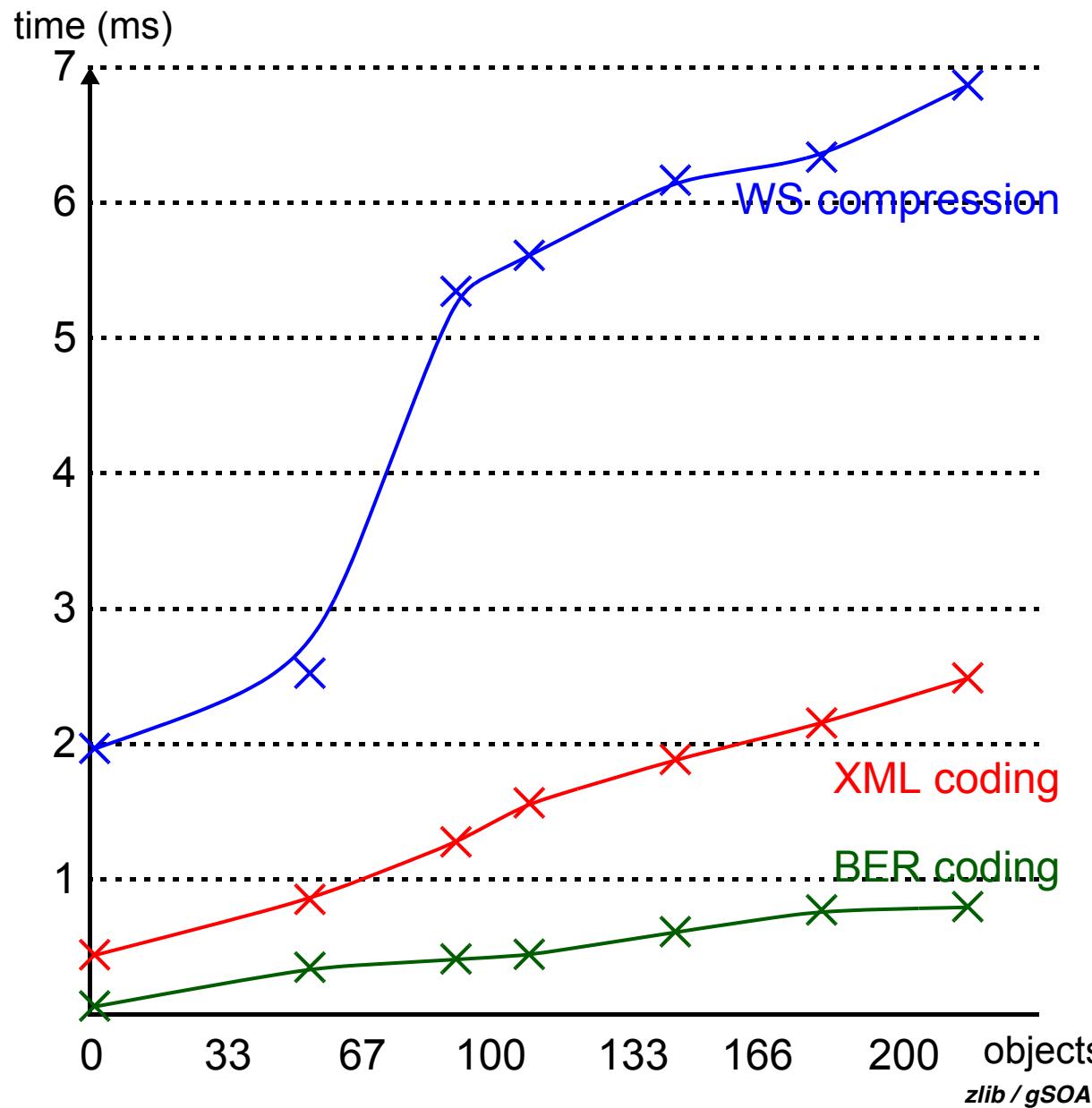
PERFORMANCE - CPU TIME - CODING & DATA RETRIEVAL

time (ms)

SNMP data retrieval

WS data retrieval

XML coding

BER coding

objects

zlib / gSOAP (V2.3.8) / Net-SNMP (5.0.9)
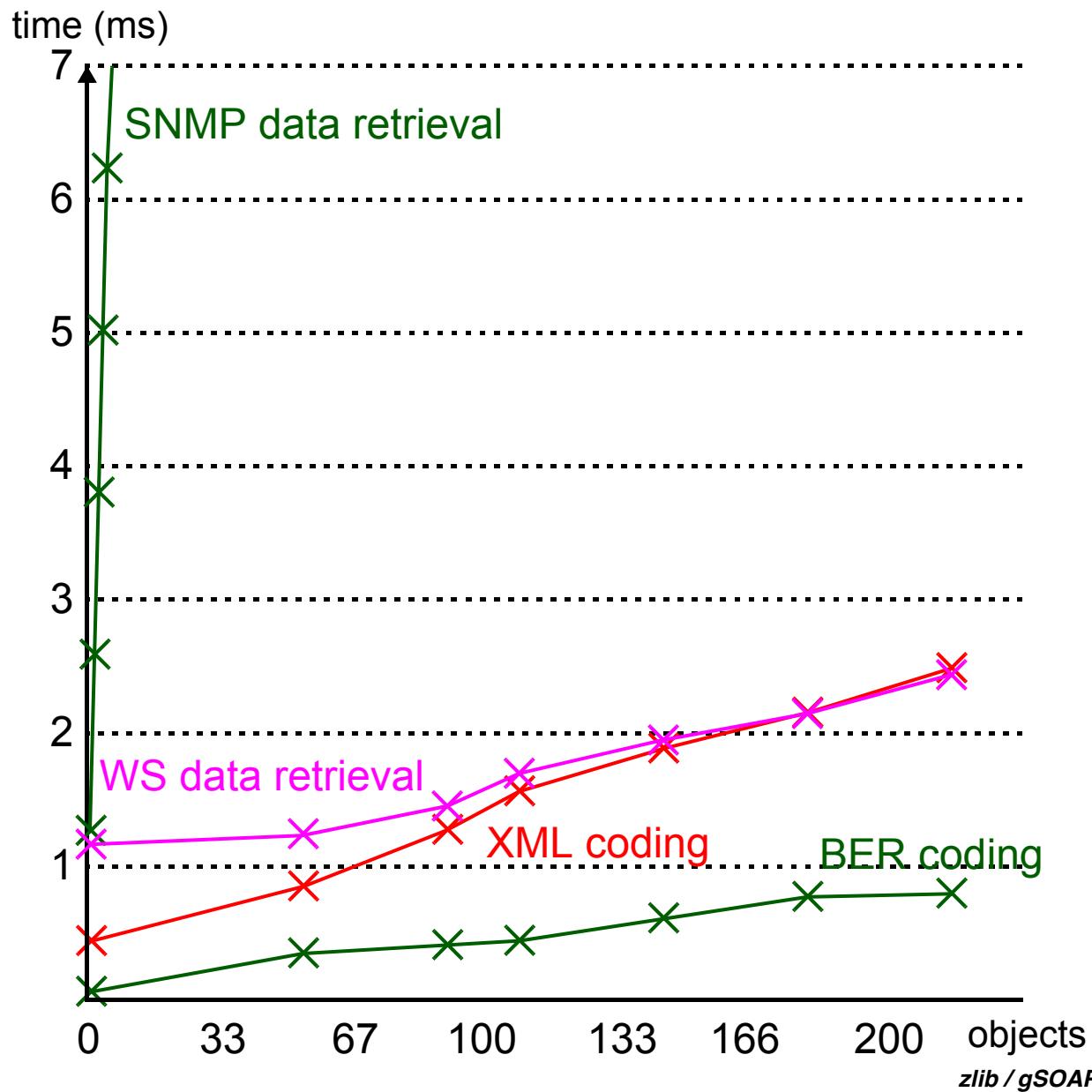
PERFORMANCE - MEMORY USAGE

| | instructions | data | |
		static	dynamic
SNMP	**1972 KB**	**128 KB**	**70 - 160 KB**
Web services	**580 KB**	**470 B**	**4 KB**

Note: zlib / gSOAP (V2.3.8) / Net-SNMP (5.0.9)

PERFORMANCE - ROUND-TRIP DELAY - 1

	1	22	66	270
WS	**1,7**	**2,6**	**10,3**	**36,5**
WS-Comp	**3,3**	**4,3**	**5,6**	**11,8**
SNMP-1	0,4	1,6	3,9	21,1
SNMP-2	0,4	1,9	5,0	
SNMP-3	0,5	1,6	4,2	
SNMP-4	0,5	1,7	4,4	
SNMP-5	0,5	1,8	4,8	
SNMP-6	0,7	2,2	5,7	
SNMP-7	0,8	1,8	2,9	
SNMP-8	0,9	1,6	3,9	
SNMP-9	0,9	6,6	18,5	
SNMP-10	1,1	1,8	3,4	58,5
SNMP-11	1,2	2,9	6,7	
SNMP-12	1,3	2,7	5,4	
SNMP-13	1,5	14,0	40,1	
SNMP-14	1,6	5,0	15,1	
SNMP-15	1,7	4,2	9,6	
SNMP-16	2,7	44,5	127,6	178,7
SNMP-17	2,7	47	140,4	251,7
SNMP-18	3,5	17,2		
SNMP-19	3,7	24,3	77,9	
SNMP-20	4,1	76,7	100,8	
SNMP-21	11,1	83,7	243,0	
SNMP-22	11,3	238,7	727,6	
SNMP-23	87,7	1822,2		

PERFORMANCE - ROUND-TRIP DELAY - SNMP GET
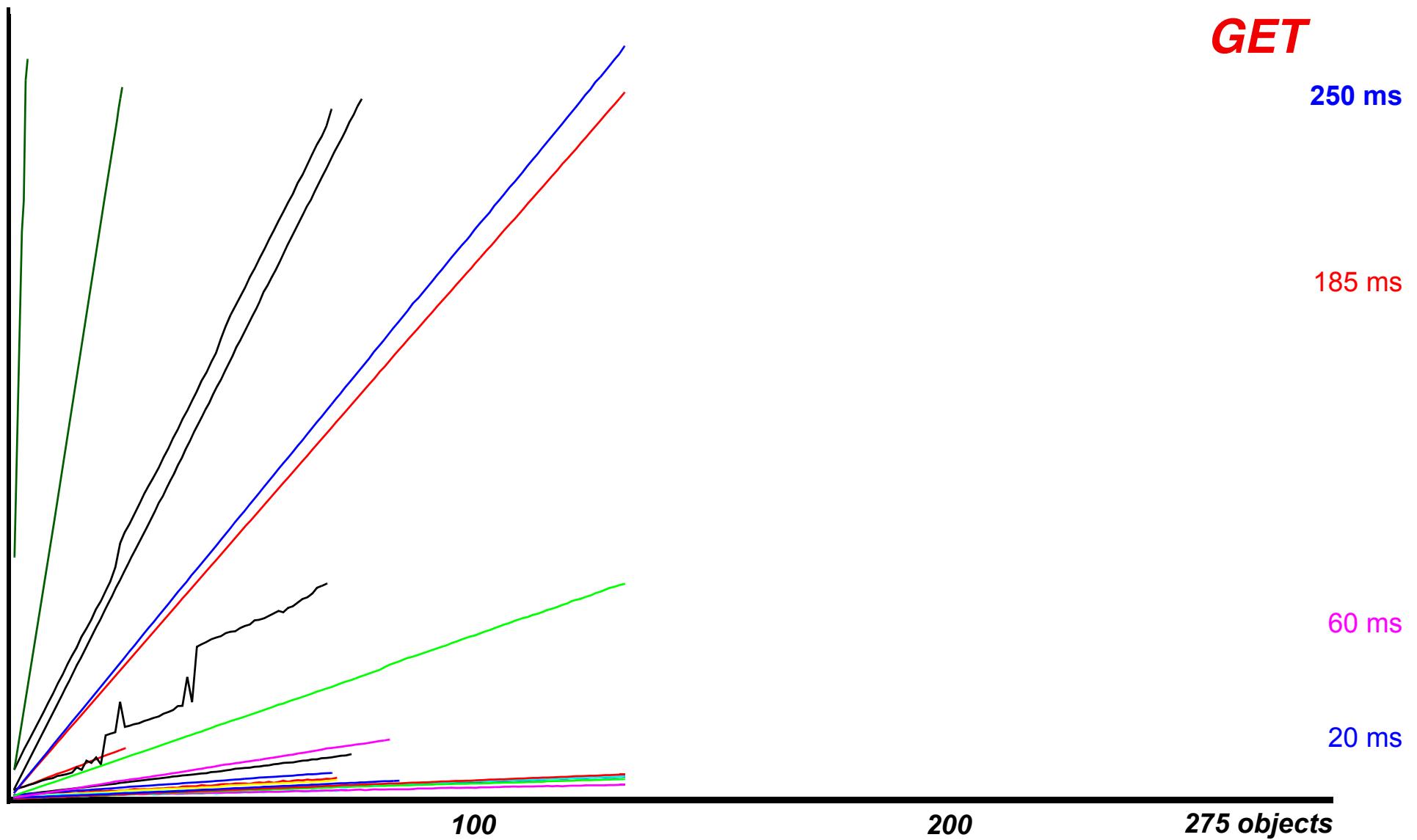
GET

250 ms

185 ms

60 ms

20 ms

100   200   275 objects

PERFORMANCE - ROUND-TRIP DELAY - SNMP GETBULK

BULK

250 ms

185 ms

60 ms

20 ms

100

200

275 objects
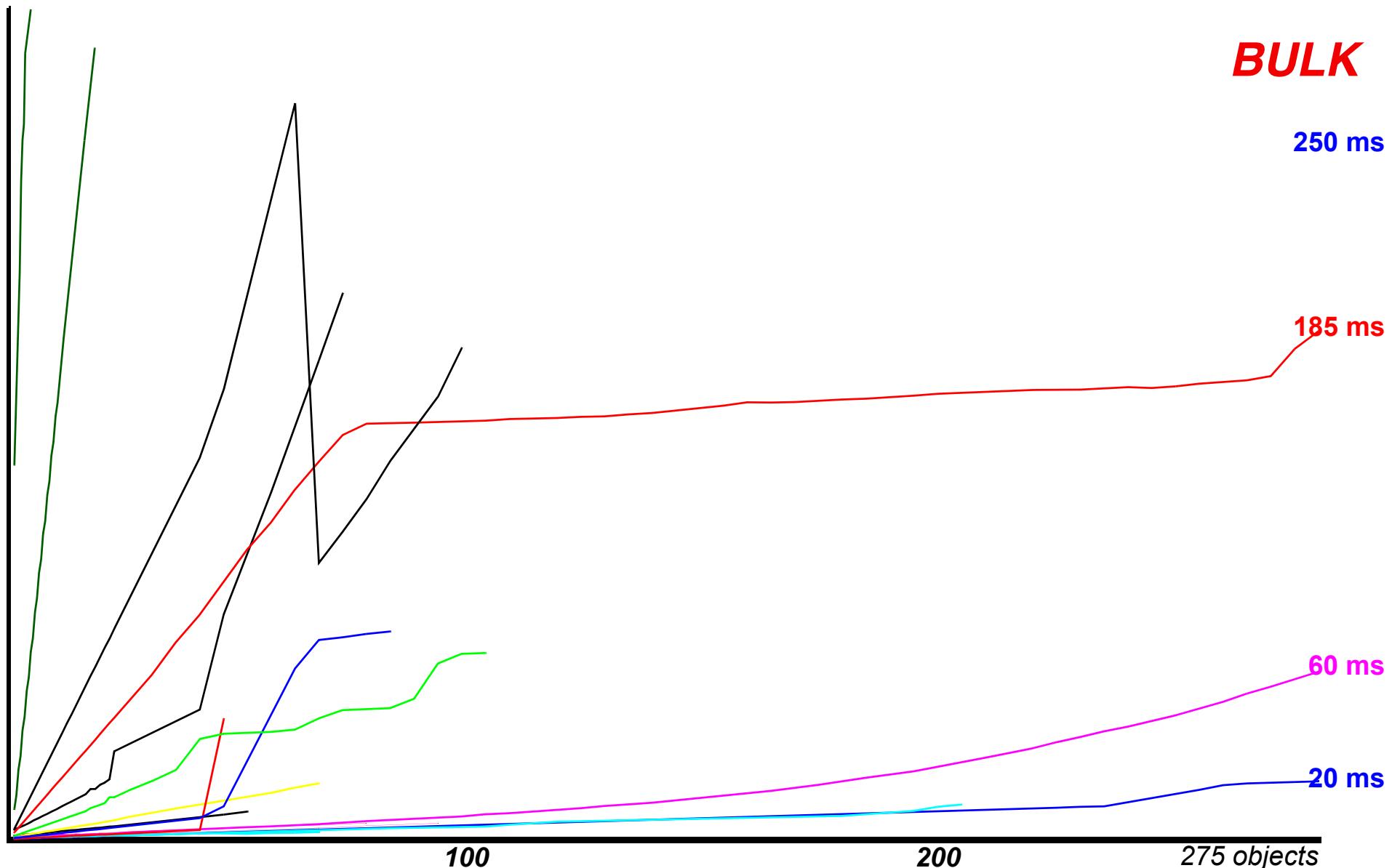
<u>OVERVIEW</u>

WHY WEB SERVICES?

WHAT ARE WEB SERVICES?

EXAMPLE & PERFORMANCE

TOOLS

CONCLUSIONS

<u>TOOLS</u>

gSOAP

WASP

easySOAP++

.NET

JBuilder

SunOne

OVERVIEW

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CONCLUSIONS

EVOLUTION OF SNMP FAILED

WE NEED REVOLUTION

WEB SERVICE IS AN INTERESTING TECHNOLOGY

MANY ISSUES STILL UNCLEAR

TOPIC FOR FUTURE RESEARCH

PERFORMANCE OF WEB SERVICES MAY NOT BE A PROBLEM

OVERVIEW

- Network management Taxonomy

- Authors and TPC members areas of interest

- Key research challenges
As identified at the 2006 NMRG/EMANICS workshop

- Key research challenges
Some private thoughts

OVERVIEW

- Network management Taxonomy

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  Some private thoughts

Goal

Define a taxonomy to organize the network and systems management research in order to:

- Classify/characterize the research in our area using a common, stable list of topics (keywords)

- Help authors to select meaningful keywords

- Identify appropriate reviewers for conference papers and journal articles review

- Track the interest of authors and reviewers in regards to the several topics of the area

Approach

Define a stable, two-level hierarchy of topics:

- First-level topics cover different dimensions of management
  - What should be managed (e.g., networks, services)
  - Which aspects should be managed (e.g., security, accounting)
  - How it should be managed (e.g., distributed, centralized)
  - How to implement it (e.g., which protocols?)
  - Which techniques should be used (e.g., simulation)

- Second-level topics specialize the first-level topics

First-Level Topics

- Network Management

- Service Management

- Business Management

- Functional Areas

- Management Approaches

- Technologies

- Methods

Second-Level Topics

- Network Management
- Service Management
- Business Management
- Functional Areas
- Management Approaches
- Technologies
- Methods

Second-Level Topics

- **Network Management**
- Service M
- Business
- Functiona
- Managem
- Technolo
- Methods

1.1.	Ad hoc networks
1.2.	Wireless & mobile networks
1.3.	IP networks
1.4.	LANs
1.5.	Optical Networks
1.6.	Sensor Networks
1.7.	Overlay Networks

Second-Level Topics

- Network Management
- **Service Management**
- Business Management
- Functional Areas
- Management Approaches
- Technologies
- Methods

Second-Level Topics

- Network Management

- Service Management

- Busine...

- Functi...

- Manag...

- Techno...

- Method...

2.1.	Multimedia service management (e.g., voice, video)
2.2.	Data service management (e.g., email, web)
2.3.	Hosting (virtual machines)
2.4.	Grids

Second-Level Topics

- Network Management
- Service Management
- **Business Management**
- Functional Areas
- Management Approaches
- Technologies
- Methods

Second-Level Topics

- Network Management
- Service Management
- Business Management
- Functions
- Management Approaches
- Technologies
- Methods

| 3.1. | Legal & ethical issues |
| 3.2. | Process management |

Information Society Technologies

EMANICS

Second-Level Topics

- Network Management
- Service Management
- Business Management
- Functional Areas
- Management Approaches
- Technologies
- Methods

Second-Level Topics

- Network Management
- Service Management
- Business Management
- Functional Areas
- Manag
- Techno
- Method

4.1.	Fault management
4.2.	Configuration management
4.3.	Accounting management
4.4.	Performance management
4.5.	Security management
4.6.	SLA management
4.7.	Event management

Information Society
Technologies

10

Second-Level Topics

- Network Management
- Service Management
- Business Management
- Functional Areas
- **Management Approaches**
- Technologies
- Methods

Second-Level Topics

- Network Management
- Service Management
- Business Management
- Functional Areas
- Management Approaches
- Techno
- Metho

5.1.	Centralized management
5.2.	Distributed management
5.3.	Autonomic and self management
5.4.	Policy-based management

Second-Level Topics

- Network Management
- Service Management
- Business Management
- Functional Areas
- Management Approaches
- Technologies
- Methods

Second-Level Topics

- N
- S
- B
- F
- Management Approaches
- Technologies
- Methods

6.1.	Protocols
6.2.	Middleware
6.3.	Mobile agents
6.4.	P2P
6.5.	Grid
6.6.	Data, information, and semantic modeling

Second-Level Topics

- Network Management
- Service Management
- Business Management
- Functional Areas
- Management Approaches
- Technologies
- Methods

7.1.   Control theories
7.2.   Optimization theories
7.3.   Economic theories
7.4.   Machine learning and genetic algorithms
7.5.   Logics
7.6   Probabilistic, stochastic processes,
        queuing theory
7.7.   Simulation
7.8.   Experimental approach
7.9.   Design

- Ne
- Se
- Bu
- Fu
- Ma
- Technologies

- **Methods**

OVERVIEW

- Network management Taxonomy

- Authors and TPC members areas of interest

- Key research challenges
  As identified at the 2006 NMRG/EMANICS workshop

- Key research challenges
  Some private thoughts

14

First level interest

Organizers, TPC members & authors areas of interest

Legend: Topics (absolute) — Members / topic — Papers / topic

15
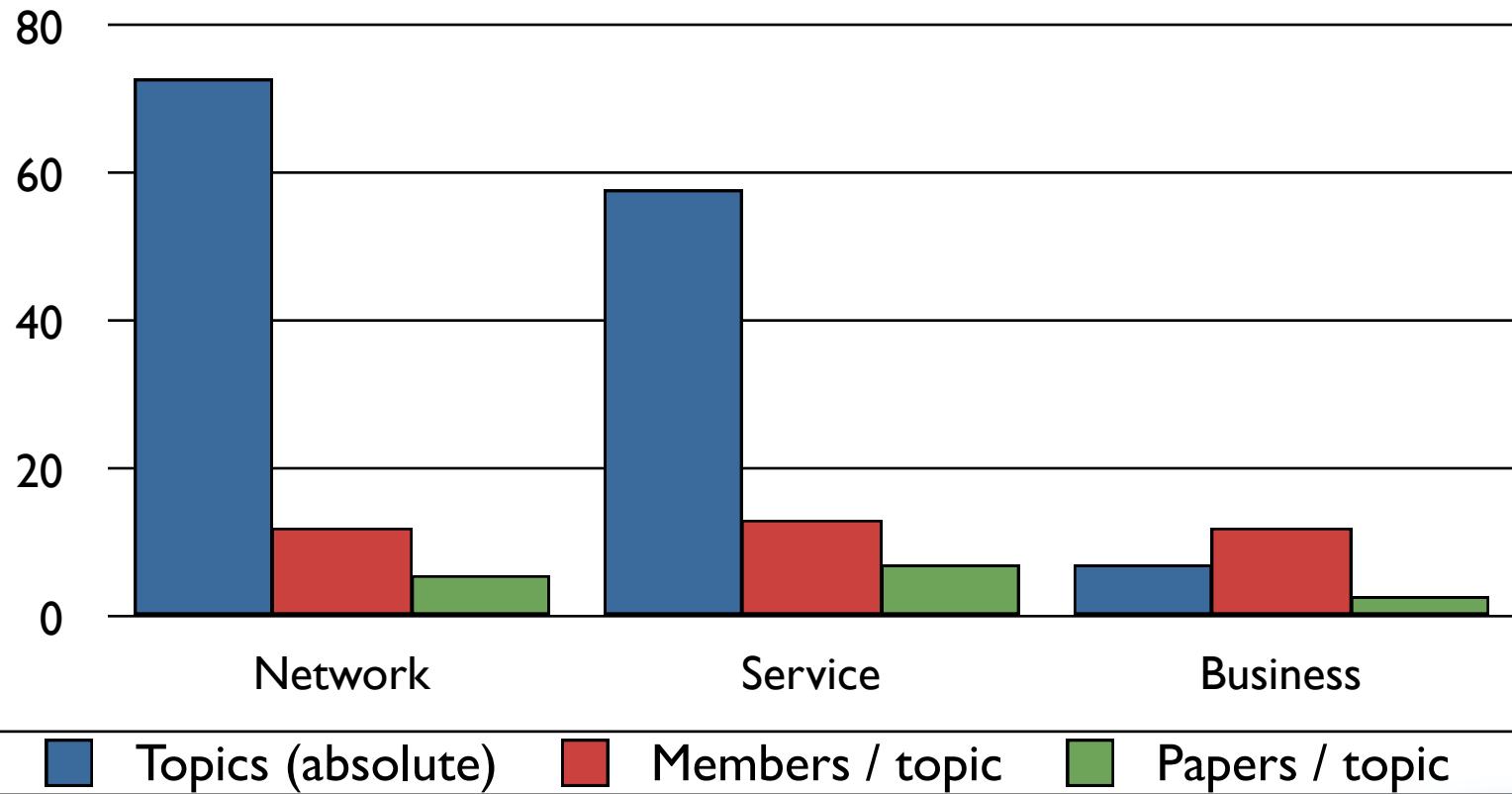
Approaches

Organizers, TPC members & authors areas of interest
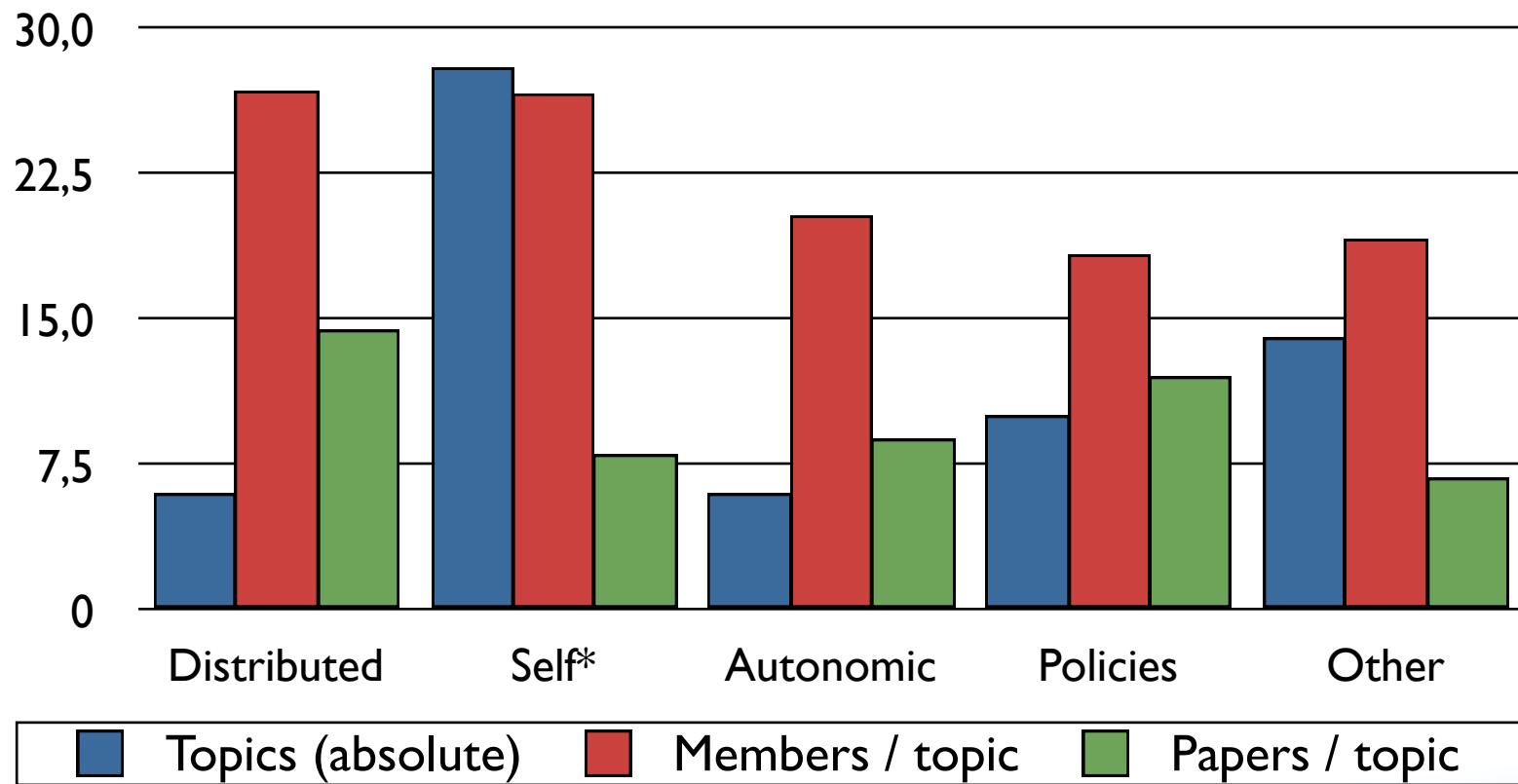
Approaches

Acceptance rate
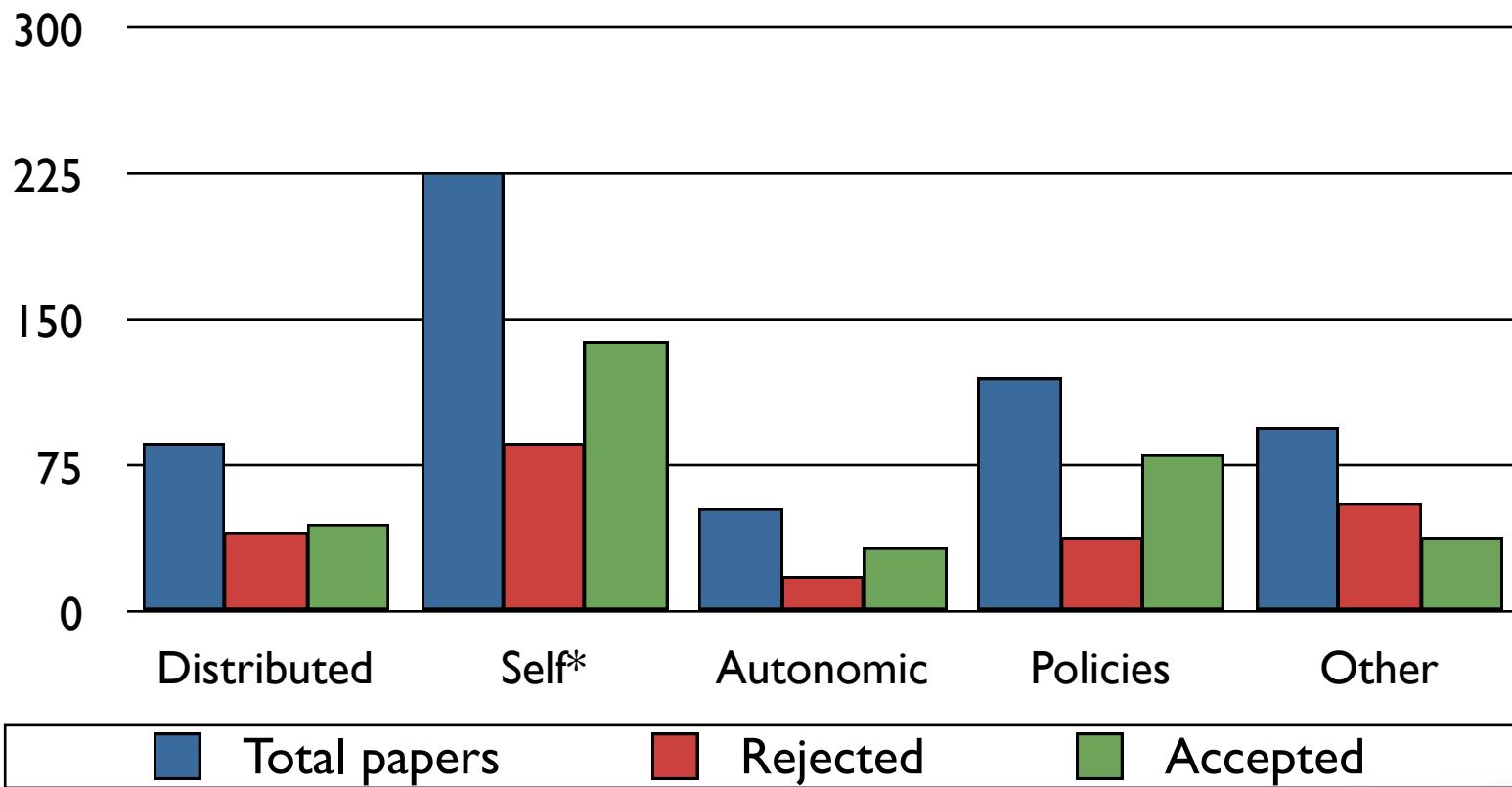
OVERVIEW

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Key research challenges
As identified at the 2006 NMRG/EMANICS workshop

Joint IRTF/NMRG and EMANICS workshop

- 19-20 October 2006, Utrecht
- Article in IEEE communications magazine, October 2007

IRTF/NMRG:

- Chartered in 1999 (chair: Jürgen Schönwälder)
- *Foster discussion between IETF, operators and researchers*

Workshop Goals

Goals:

- Bring together researchers, operators, vendors and technology developers

- Identify promising future directions of network management research.

- Outcome should be a description of research directions that is felt worthwhile to explore in the next 5 years.

Non-goal:

- Define what management standards are needed now

Information Society Technologies

EMANICS

Workshop Organization

- Invitation via NMRG list to submit position statements

- 20 participants:
  - Alcatel/Lucent, Avaya, Cisco, Ericsson, HP, Huawei, NEC
  - Orange France Telecom, Korea Telecom, Switch, Tiscali
  - Researchers from EMANICS, as well as from elsewhere
  - 60% from Europe

- Day 1: presentation / discussion of position statements

- Day 2: parallel vendor / operator / researcher sessions

- Day 2: plenary discussion of session results

Research challenges

- Management models
- Distributed monitoring
- Data analysis and visualization
- Economic aspects of management
- Uncertainty and probabilistic approaches
- Ontologies
- Behavior of managed systems

Management models

- We understand:
  - Manager-Agent approach (client-server)
  - Hierarchical management (DisMan, TMN)
- We do *not* understand
  - Fully distributed management (P2P, ad-hoc)
  - Autonomic and Self-* technologies (auto-configuration, stability of control loops)

Distributed monitoring

- Examples of what is needed:
  - track number/quality of VoIP calls
  - find best proxies / peers (P2P)
- Goal: a lightweight, distributed monitoring layer offering aggregates of local info to applications
  - Sum, average, extreme, percentile, histogram, …
  - Difficulty: bandwidth and CPU usage -> lightweight!
  - Find trade-offs
  - Tree-based versus gossip-based protocols

Data Analysis and Visualization

- We can create:
  - Topology maps for small networks
  - Static time series plots
- We have problems with:
  - Maps for large, multi-layer networks
  - Online analysis at Tbps
  - Visualization of anomalies
  - Real-time, interactive visualization techniques (zooming, filtering, correlating)

Economic Aspects

- Most researchers focus on technical solutions
- Limited research into the operational costs of such technologies:
  - IntServ/DiffServ versus overprovisioning
- Research needed on models to estimate costs
- Network management is risk management

Uncertainty and Probability

- Many researchers focus on deterministic approaches
- Scalability problems force us to rethink in terms of uncertainties and probabilistic approaches:
  - Probabilistic SLAs / statistical guarantees
  - Manager may not have a complete overview
- How to decide between probabilistic and deterministic approaches?

Ontologies

- Data modelling is believed to be understood

- Research is needed:
  - If / how ontologies can be effectively used to automate the implementation of management interfaces
  - If / how ontologies can help to check / enforce policies and behaviour

Behavior of Managed Systems

- Management models usually represent state:
  - MIBs, CIM
- Research is needed to model and manage behavior:
  - Normal versus abnormal behavior
  - Detect resource failure, intrusions, …
  - Design self-stabilizing systems

OVERVIEW

- Network management Taxonomy

- Authors and TPC members areas of interest

- Key research challenges
  As identified at the 2006 NMRG/EMANICS workshop

- Key research challenges
  Some private thoughts

Key research challenges
Some private thoughts

- Focus too much on design of technologies

- We do not understand the basics (anymore)

- Researchers hardly measure

- There is little interaction with operators

Focus too much on design of technologies

- Too many papers on these already

- Yet another approach

- Problem definition generally weak

- Comparison with alternatives generally missing

- **Community needs common metrics**

- Basic assumptions not well defined
  - 90% of the papers on self* do not define the term
  - 10% of the papers on self* give obvious definitions

We do not understand the basics (anymore)

Example: Autonomic management

- Some claim this is the core of the future Internet

- Others claim there is nothing new

- 2007 Dagstuhl workshop
  - Day 1: what is autonomic (compared to self*, autonomous)
  - Day 2: what is management?

Community need books / teaching material

What is management?

- Network management is the act (art) of initializing monitoring and modifying the operation of the primary network functions [Pras]

- Network management includes all the activities needed to keep the network running and evolving in such a way that it both satisfies the user needs and the provider constraints [Festor]

- Network management determines the supervision of networked systems to ensure that they behave according to some pre-defined goals [Stiller]

- A management system is a distributed system that monitors and controls another distributed system [Stadler]

What is management? - Discussion

What is management? - Discussion

- Should there be a human being in the loop?
  - brainware

What is management? - Discussion

- Should there be a human being in the loop?
  - brainware

- What is the difference with control?
  - management operates on large time-scales?

What is management? - Discussion

- Should there be a human being in the loop?
  - brainware

- What is the difference with control?
  - management operates on large time-scales?

- Can management functions be included into the design?
  - or should management be added in the operational phase?

Management and cyclic design
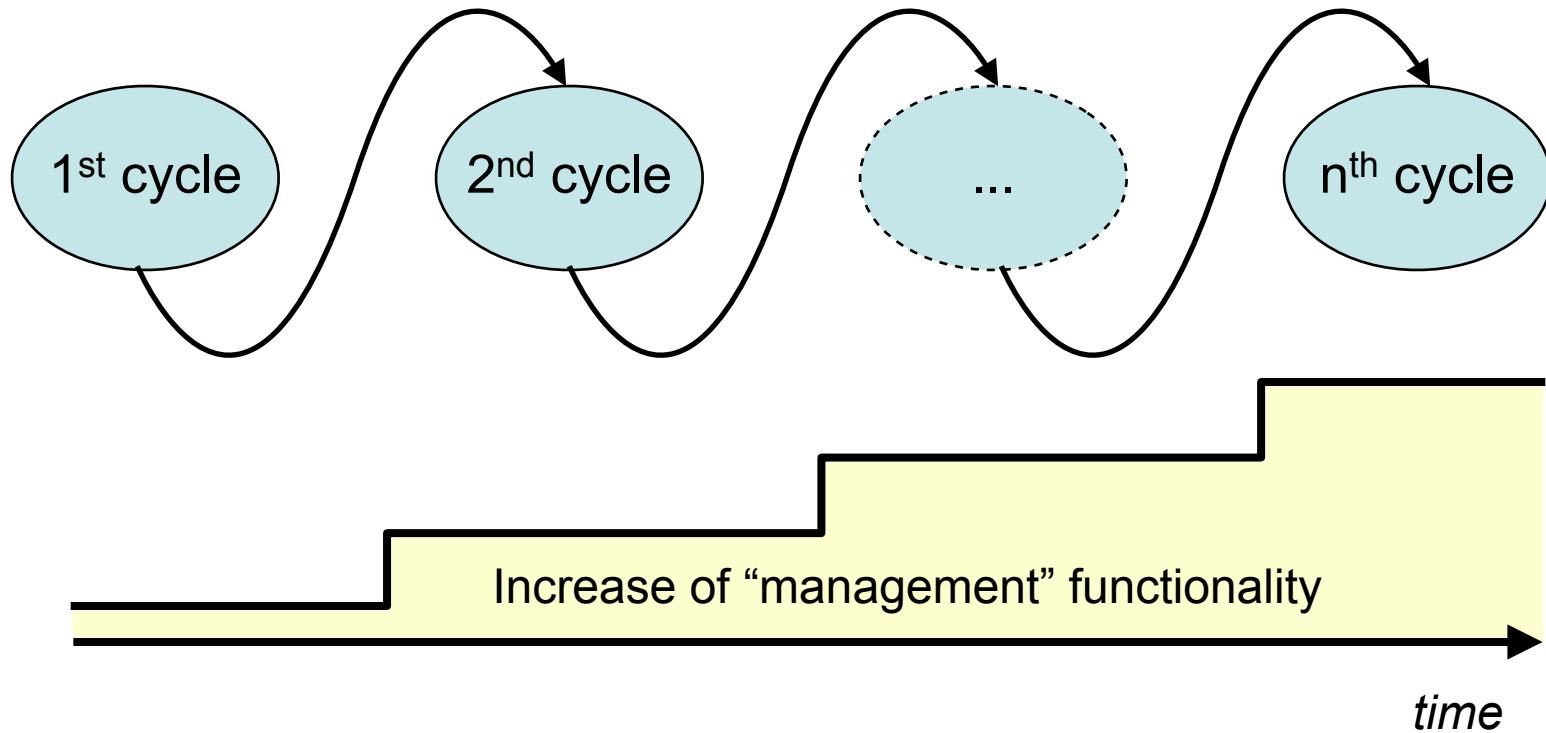
From explicit to implicit management
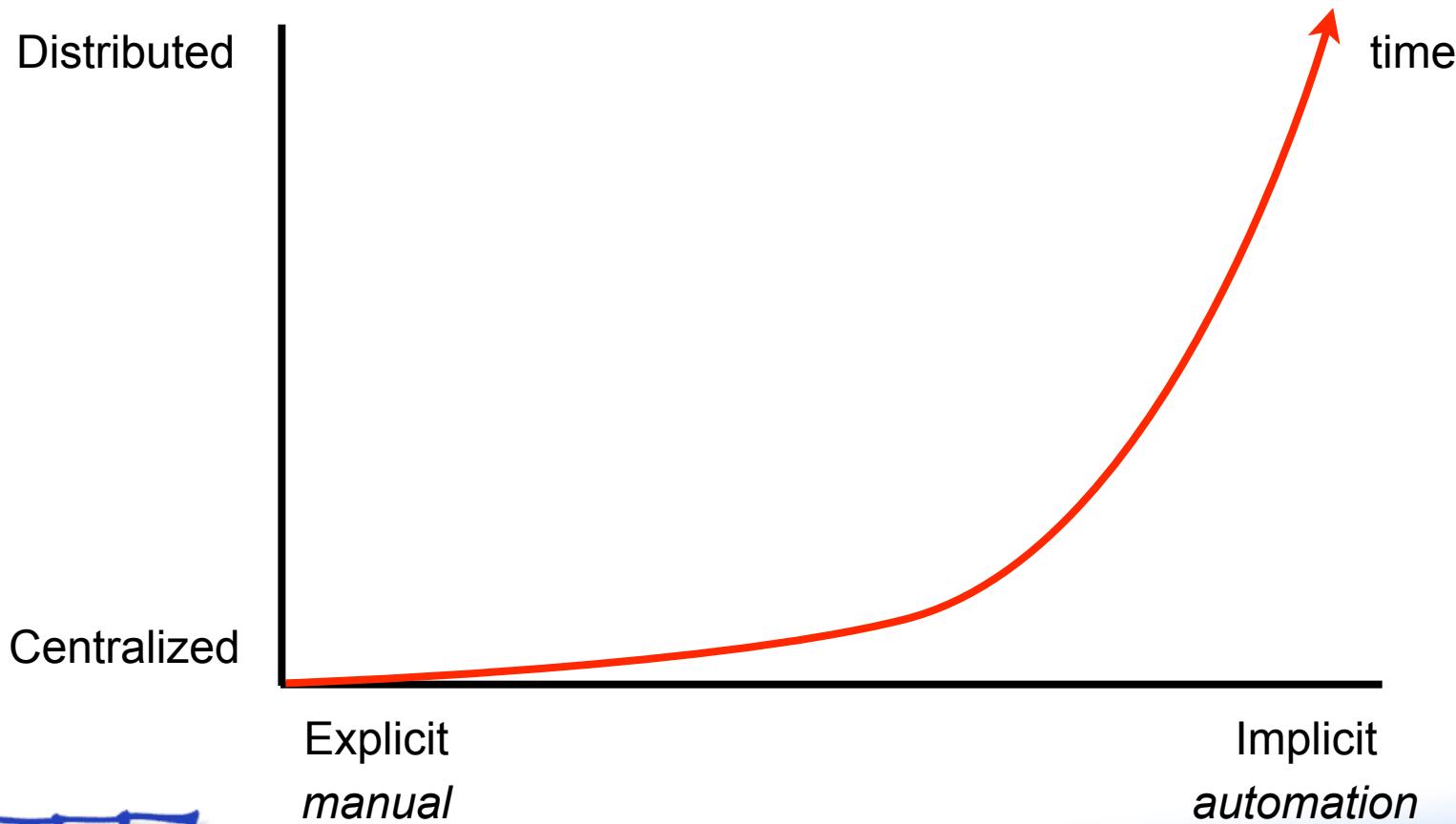
Researchers hardly measure

- How can you manage, without knowing?
- Network traces are essential
- Capturing data is hard
  - Gbps
  - From packet to (sampled) flows
- Example: security management
  - Many researchers still use DARPA'99 data
- *Lot of work needs to be done!*

Interaction with operators

- Only operators know the problems
- Getting data requires a trust relationship
- Invest in such relationships!
- Join projects!