SCA for the Above 2 GHz Waveforms

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Agenda

- Government Mandates for Above 2 GHz implementation
- Software Communication Architecture
- Challenges for Above 2 GHz Waveforms
- Demonstration Platform
- Performance considerations
  - Ethernet
  - CORBA
- Conclusions

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US Government Mandate

- The Assistant Secretary of Defense Jun 17, 2003 Letter – Radio Frequency (RF) Equipment Acquisition Policy
  - Policy is hereby modified to specifically reflect that all such systems; including those operating above 2 GHZ, are required to be developed in compliance with JTRS/SCA. The Policy is now applicable to all communications waveforms/systems that operate at or above 2MHz.
  - By specifically expanding this policy beyond 2 GHZ, space-based laser and RF communications can be seamlessly integrated in airborne and ground based networks through an appropriate networking service layer being developed for JTRS/SCA radios.

- Creates new challenges for waveforms, which were difficult to begin with.

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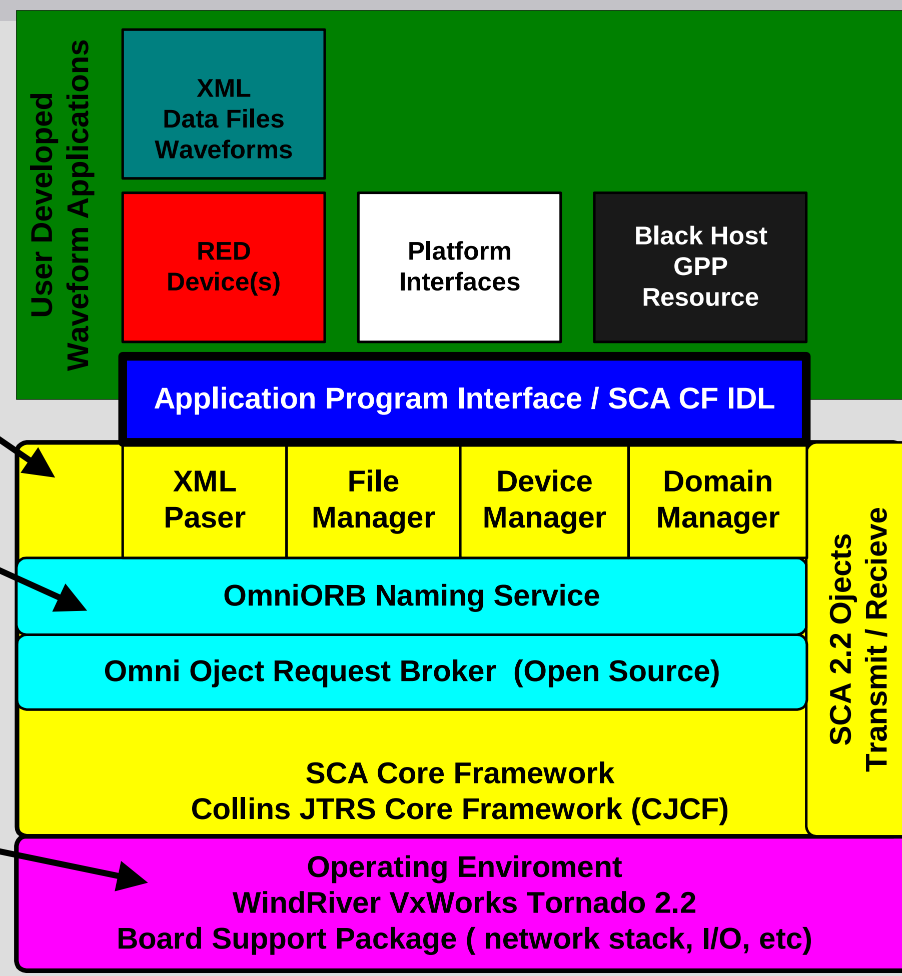
Software Communications Architecture (SCA)

Background Slide

- Core Framework SCA 2.2
  - Device Manager
  - Domain Manager
  - File Manager
  - GPP device
  - XML Parser
- CORBA Transport
  - OmniORB – IDL complied SCA 2.2
  - Naming Service
  - Open Source Solution for CORBA transport
  - Changes implemented to support VxWorks
- RTOS
  - vxWorks – has POSIX compliance needed for SCA
  - Board Support Package
    - (with drivers for Ethernet)



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SCA for MILSATCOM Waveforms

- The goal is to produce MILSATCOM waveforms that adhere to the SCA specification to provide the greatest potential for portability.
    - Major SCA functionality of waveform portability is related to instantiation, execution, and teardown of the waveform.
- CORBA provides many advantages over low-level programming interfaces, such as the TCP/IP.
    - Among these advantages are extensibility, maintainability and reusability of the current SCA implementations
    - One of the major disadvantages is the time required to marshal data to/from CORBA (i.e. latency).
    - The SCA mandates the use of CORBA to allow for control of waveforms and management of the waveforms, but also allows the use of non-CORBA methods.

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Challenges for > 2GHz SCA Waveforms

- Primary concern is data throughput
  - Data rates for MILSATCOM are only increasing
  - Large amount security data on top of message data
- System Throughput Latency
  - NSA adds requirements which force real time behavior
- JTRS Compliance
  - The Joint Tactical Radio System is the current standard for SCA implementation
  - Contracted by the Joint Program Office
  - A successful > 2GHz implementation must be interoperable with JTRS
  - Not originally designed for > 2GHz waveforms
  - Adds requirements for size, weight, power.
  - Adds a Modem Hardware Abstraction Layer

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Software Consideration for > 2 GHz

- Operating Environment (OE)
  - RTOS and CORBA ORB used low latency and integration flexibility
  - Open Platform for extensibility
  - COTS software support
- SCA 2.2 requirements and design implementation concerns
  - Ability to partition software to support changes to SCA as it evolves
  - Ability to partition software from hardware to support hardware abstraction layer (HAL)
  - I/O and control variability
- Data Rates / Data Latency and simultaneous waveform operations
  - Future Waveforms
    - May stress hardware / software implementations
    - Hardware / Software integration to achieve desired data rates of future waveforms
  - Waveform objects and packets sizes
  - COTS Ethernet Stacks (Performance)

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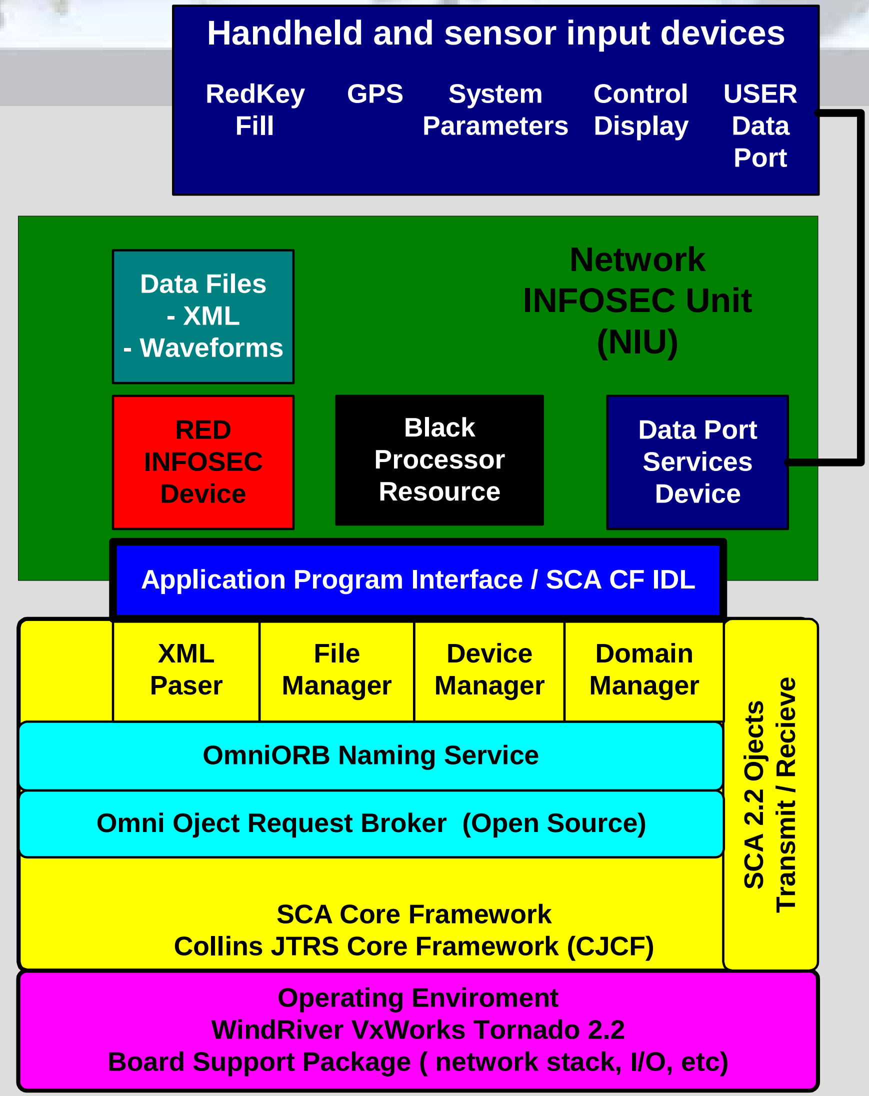
Network Infosec Unit (NIU) Software Architecture

- RED INFOSEC Device
  - Software components to support TRANSEC processing
- Black Host Processor
- Black INFOSEC Manager
  - Interface to red processor and TRANSEC generator
- Data Port Service
  - Used to read external user input devices and sensors
  - Based on Push / Pull transfer
  - Handheld
  - GPS, KY- 99
- Data Files
  - Storage for XML waveform files
  - Waveform applications
- Common Software
  - CJCF, RTOS



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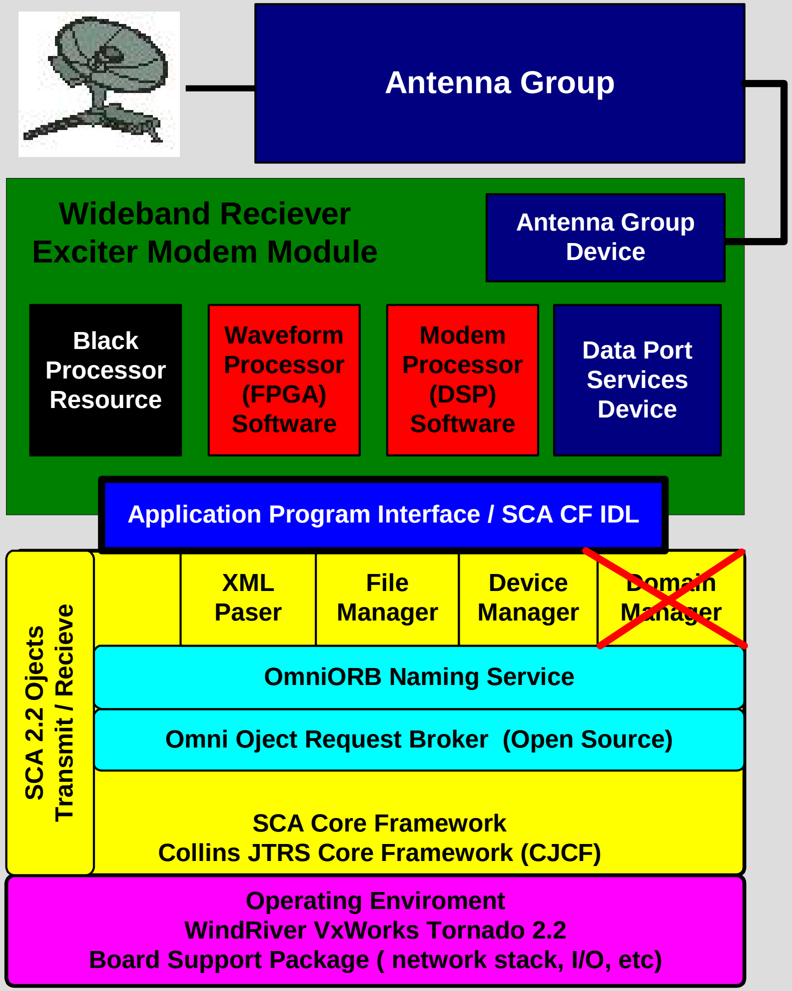
Receiver Exciter Modem Module (REMM) Software Architecture

- Wave Processing and Modem
  - Modem software – Modem DSP / XCVR
  - Waveform Processor – Synchronization of uplink / downlink
- Data Port Client
  - Support remote interfaces to GPS PLGR, Handheld Control, KY- 99, via NIU
- SCA Operating Environment
  - CJCF software independent of hardware implementation
  - Not including Domain Manager



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Putting it together

- Based JTRS Cluster 1 JTRS Rack
  - UT replaced with WB REMM
  - 2 Pitch JTRS Module
- WB REMM Prototype
  - Developed from past years IR&D and SCAMP-SEP, and our Cluster 1 experiences
  - Based on needs determined by future military needs
- NIU Prototype
  - Based on requirement for 1 Gb Ethernet backplane interface
  - Same functionality
- Software
  - Reuse of Collins JTRS Core Framework (CJCF) from Step 2A and Step 2B development
  - LDR Software – reused from SCAMP SEP LDR
  - Use of commercial off the shelf software for RTOS, CORBA and XML parser technology

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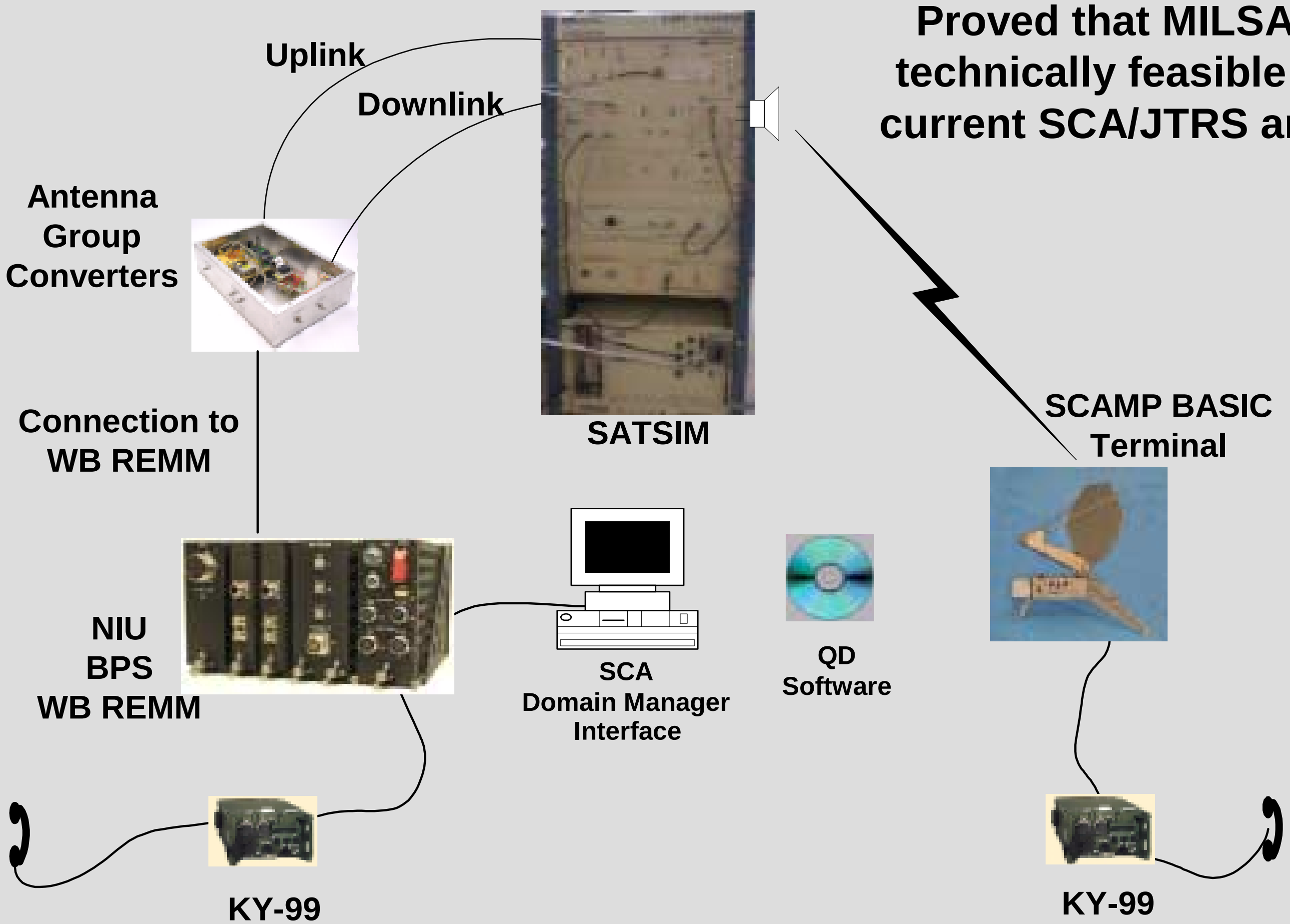
Successful Demonstration

Proved that MILSATCOM is technically feasible using the current SCA/JTRS architecture



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Future > 2 GHz Waveform Considerations

- Nearly all of the >2 GHz waveforms are full duplex, which means that transmission/reception are performed simultaneously.
- Above 2 GHz waveform processing requires high speed.
  - Downlink will be at or above user data throughput of the backplane for 100Mb.
  - Backplane should be designed to handle an equal data rate for uplink/downlink. Provides the greatest flexibility.
  - Cluster 1 backplane is provisioned for a 1 Gb Ethernet interface.
    - Note: current JTRS development is 10/100 Base Ethernet

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SATCOM Waveform Data Rates

Above 2 GHz Characteristics		
Service	**Frequency**	**User Data Rate**
DSCS III WGS X-band	8/7 GHz	2.4 Kbps - **20 Mbps**
WGS Ka-Band	30/20 GHz	256 Kbps - **52 Mbps**
GBS	30/20 GHz	1.5 Mbps - **25 Mbps**
Milstar LDR	44/20 GHz	75 bps - 2.4 Kbps
Milstar MDR	44/20 GHz	4.8 Kbps - 1.544 Mbps
AEHF XDR	44/20 GHz	75 bps - 8.192 Mbps
TCDL	14.4 - 15.3 GHz	200 Kbps/2Mbps/ 10.7/**45 Mbps**
CDL	X-band & 14.4 - 15.3 GHz	200 Kbps/2Mbps/ **10.7/45 Mbps/ 137/274 Mbps***
TSAT (XDR+, etc.)	SHF & EHF bands	**< 274 Mbps** **XDR+ < 45 Mbps**

Extremely high user data rates will continue to increase processing needs for Software Define Radio Architectures for SATCOM Radios

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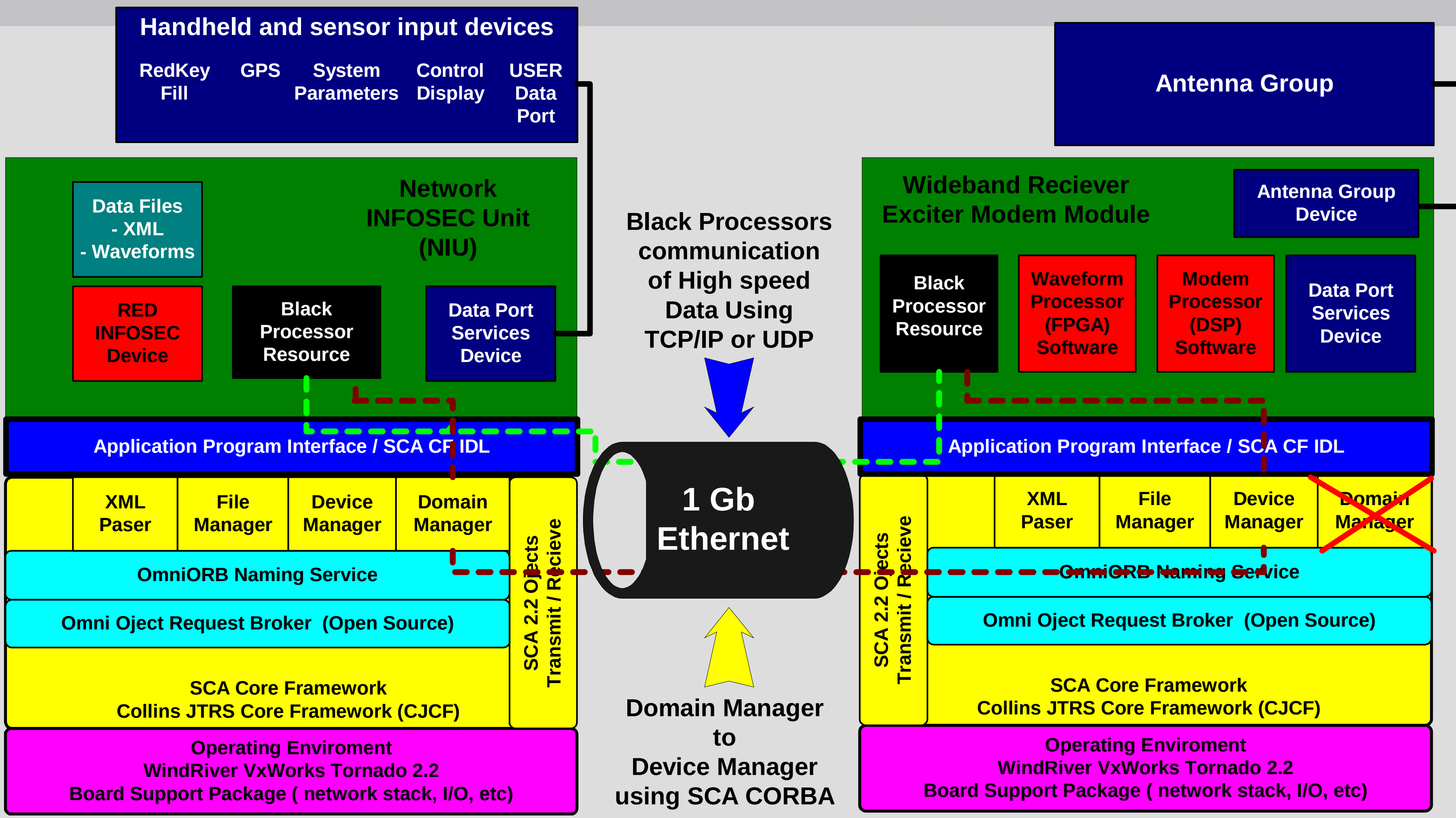
Gb backplane for more data



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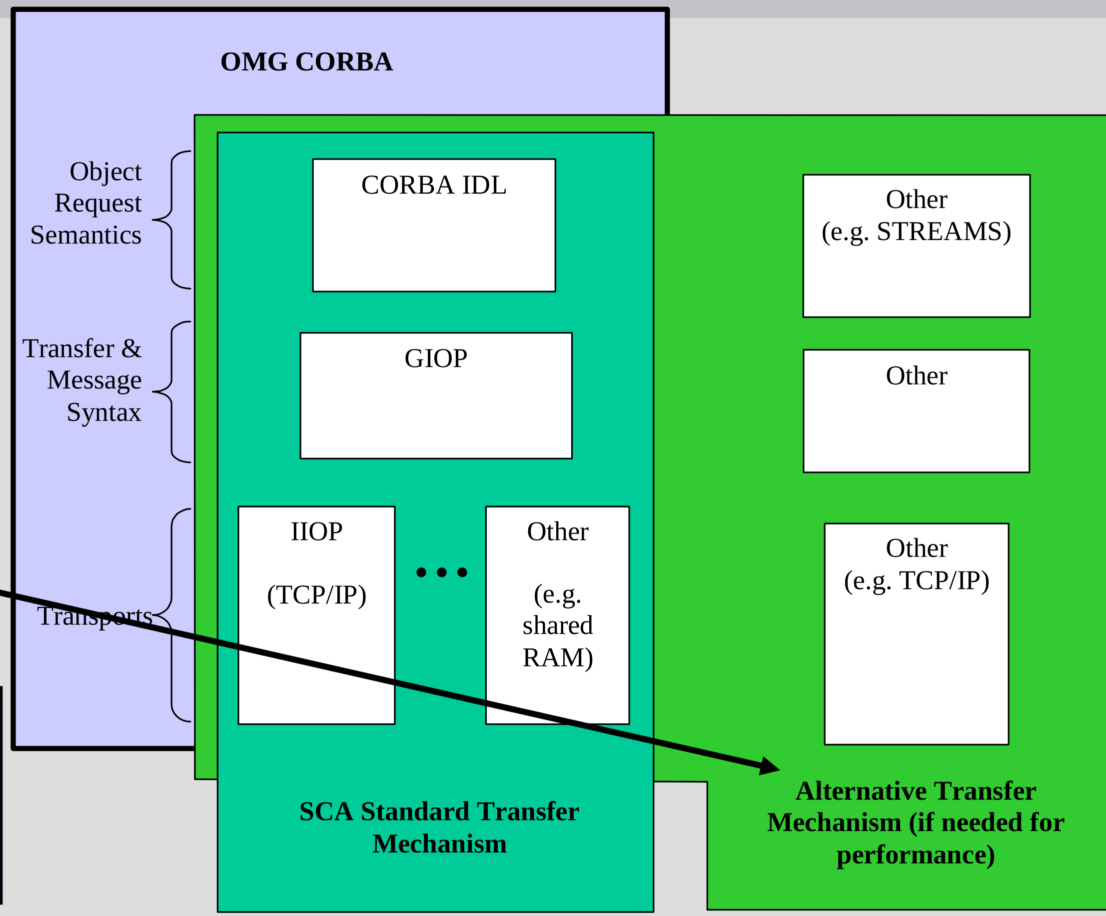
SCA Specification MSRC-5000SCA

3.2.1.2.2 API Transfer Mechanisms.
A Transfer Mechanism provides the communication between a service provider and a service user that may be co-located or distributed across different processors.

Figure 3-35 shows the standard and alternate transfer mechanism structure for APIs.



SCA allows the use of lower level API's such as TCP/IP or UDP to transfer data

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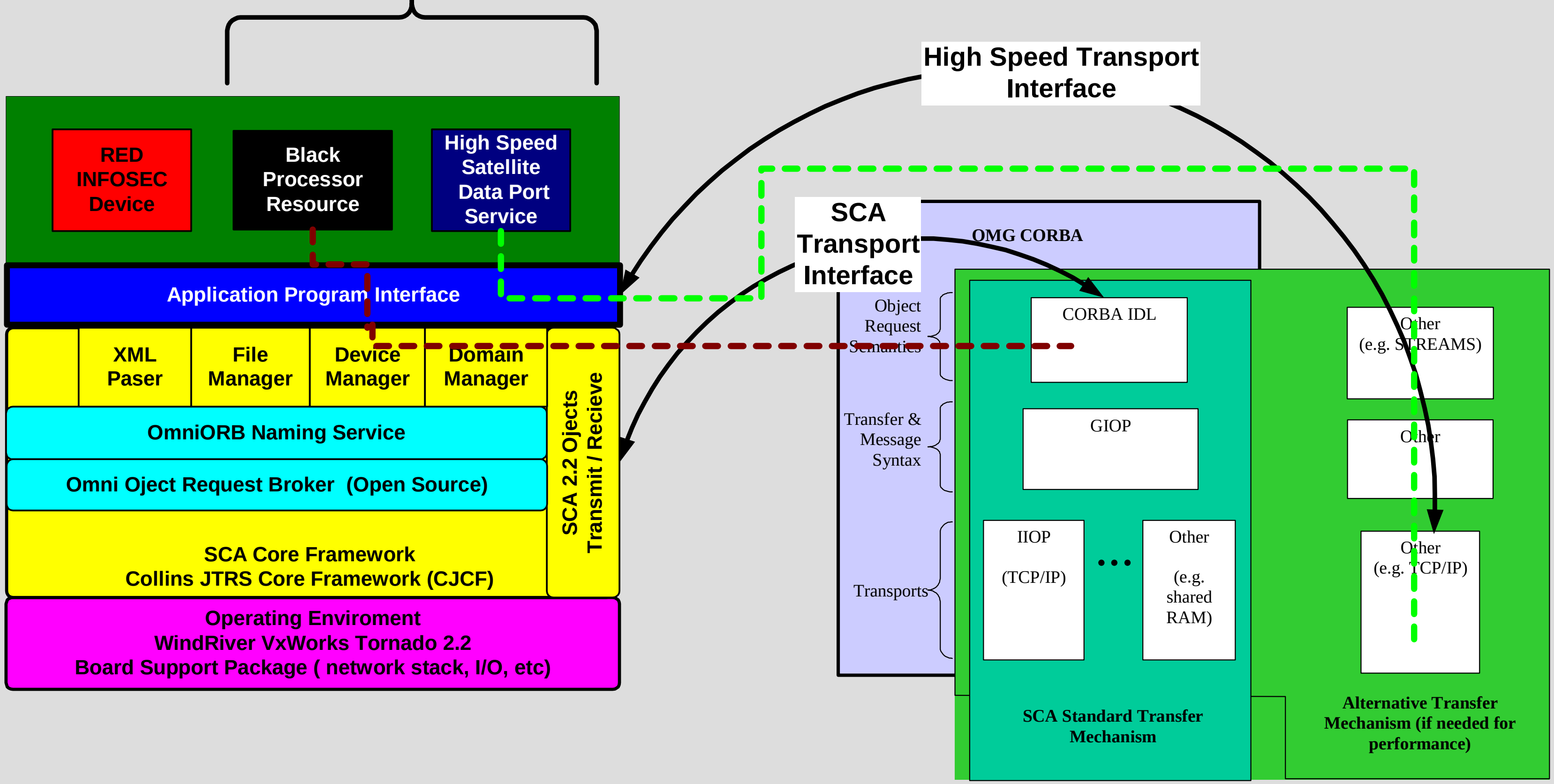
Alternate Transfer Method of SCA

Terminal data is controlled and managed with SCA to maintain waveform portability. When high speed uplink / downlink is needed, the data is transmitted by an alternate transfer method using (TCP/IP or UDP).



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Ethernet Behavior Modeling

- The model incorporates 3 transport mechanisms: UDP, TCP and CORBA.
  - UDP should represent the max data rates that can be attained over the backplane.
  - TCP should represent the max data rates with acknowledgement
    - include round trip acknowledgement of data.
  - CORBA uses TCP transport mechanism within GIOP. The Time differences between CORBA and TCP should include overhead associated with:
    - Marshalling the user data
    - Adding the appropriate GIOP header information

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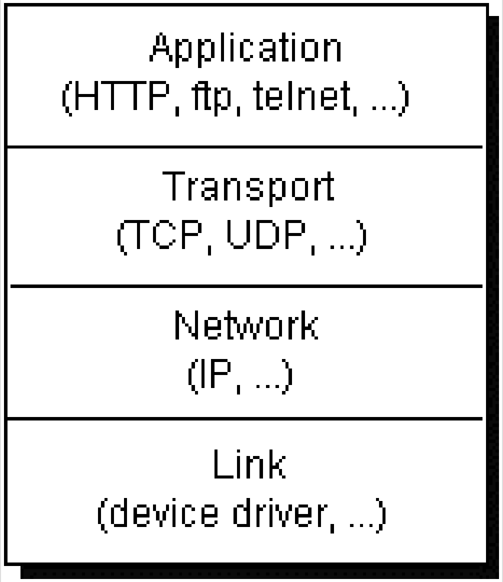
Background Slide

What is IP, TCP and UDP

- Internet Protocol (IP) - IP serves as the electronic post office by ensuring that messages get to the right address or addresses.
  - IP is the Internet's most basic protocol. In order to function in a TCP/IP network, a network segment's only requirement is to forward IP packets. In fact, a TCP/IP network can be defined as a communication medium that can transport IP packets. Almost all other TCP/IP functions are constructed by layering on top of IP. IP is documented in RFC 791, and IP broadcasting procedures are discussed in RFC 919.
- User Datagram Protocol (UDP) - Transport layer protocol in the TCP/IP protocol suite used in the Internet.
  - UDP, documented in RFC 768, provides users access to IP-like services. UDP packets are delivered just like IP packets -- connection-less datagrams that may be discarded before reaching their targets. UDP is useful when TCP would be too complex, too slow, or just unnecessary.
- Transmission Control Protocol (TCP)
  - The Transmission Control Protocol (TCP), documented in RFC 793, makes up for IP's deficiencies by providing reliable, stream-oriented connections that hide most of IP's shortcomings. The protocol suite gets its name because most TCP/IP protocols are based on TCP, which is in turn based on IP.



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Benefits of TCP

- **For TCP the receivers confirm the successful receipt of data before additional data is transmitted.**
  - **If an error occurs in the transmission, the TCP sender automatically retransmits the correct data.**
  - **TCP data rate measurement is typically based on the round trip of data that includes the returned ACK.**
  - **TCP data rates are typically less consistent since they require that both the sender and receiver are syncing to the data.**

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Benefits of UDP

- UDP is a connectionless protocol. There is no feedback mechanism from receiver to transmitter.
  - With no feedback path with UDP, data can be transmitted much more quickly.
  - UDP can be used for short haul connections. For example, inside a cabinet or within a network of well defined connections the unreliable connectionless protocol concerns can be overcome.
  - TCP was developed for long haul transmission that may go through many routers/switches before reaching the end destination.
  - UDP method could be used also when the ACK/NCK is not necessary.
  - UDP also provides a better method to manage the link layer in a well known and controlled environment control of (latency and buffering) of data.
  - UDP is being deployed in new aircraft systems for display and control functions in the cockpit.

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Ethernet Behavior Model Assumptions

- Analysis assumes:
  - No lost data, no retransmits, no delay (with some exceptions)
  - Data packets of varying sizes from 128 to 131072 bits are transmitted.
  - Max frame sizes for TCP is used and no runt frames are generated.
  - Data for 100Mb is routed through an Ethernet switch set for 100Base-Tx transmission.
  - Data for 1Gb is routed through an Ethernet switch set for 1000Base-T transmission.
  - Computer hardware and network equipment can sustain the peak TCP allowed data rates.
  - Values include overhead associated with transport method used.
  - This simulates the performance of a single application, not an aggregate usage model of multiple simultaneous users on a JTRS backplane
  - This does not incorporate any SCA overhead associated with device setup, teardown, or data port operations.

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O.S. Stack and ORB Software

- The study did not perform any modification to the O.S. Stacks or OmniORB software
  - Performance modification may enhance the performance (study is ongoing)

- The O.S stack software is configured to use the RFC-1323 modifications which may be considered a performance modification for large data packets.
  - In Basic TCP, the maximum number of bytes that can be in transit (specified by the TCP receive window size) is limited to 64KB by the 16 bit window size in the TCP header. Often the 64KB value is used to illustrate the maximum theoretical throughput of TCP. This is only partially true.
  - In the early 1990s Van Jacobsen et Al. recognized that higher bandwidths were becoming available and that TCP needed to be updated to support high bandwidth, high latency networks.
  - The work culminated in 1992 with the publication of RFC1323 which specified modifications to TCP to support the high bandwidth, high latency networks. This removed the 64 KB limit, in theory.

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Testing Data Collection

- Testing is based on varying packet sizes for both 100 Base-Tx and 1000 Base-T backplane speeds
- Testing data excluded any abnormal data that was > 10x, typically when transitioning from different packet sizes the first data packet was not consistent with prior or average data and was thrown out of the calculations.
- The linear data is an approximation of data seen over a large number of packet sizes and test sequences.

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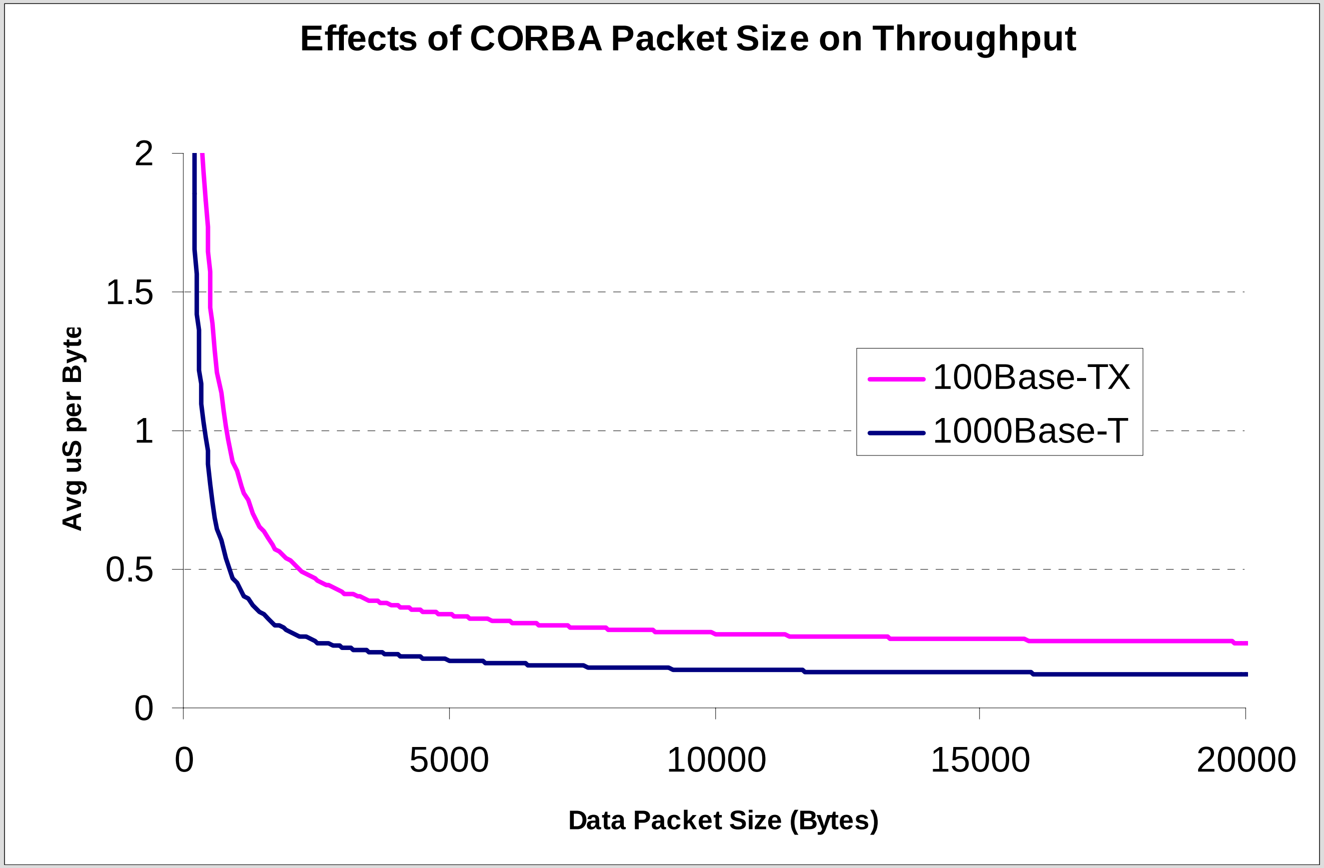
CORBA Data Rates

Larger packet sizes reduce the average time per byte



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Conclusions

- Since the physical transport increased by a factor of 10, but the throughput only doubled, it is reasonable to conclude that the limiting factor is not the physical layer on the 1000Base-T tests. The computer boards used for the tests can only create data packets at a certain speed. It is concluded that the throughput limit is a result of the processor speed not a physical channel limit.

- The processors used were 533 MHz PPC.

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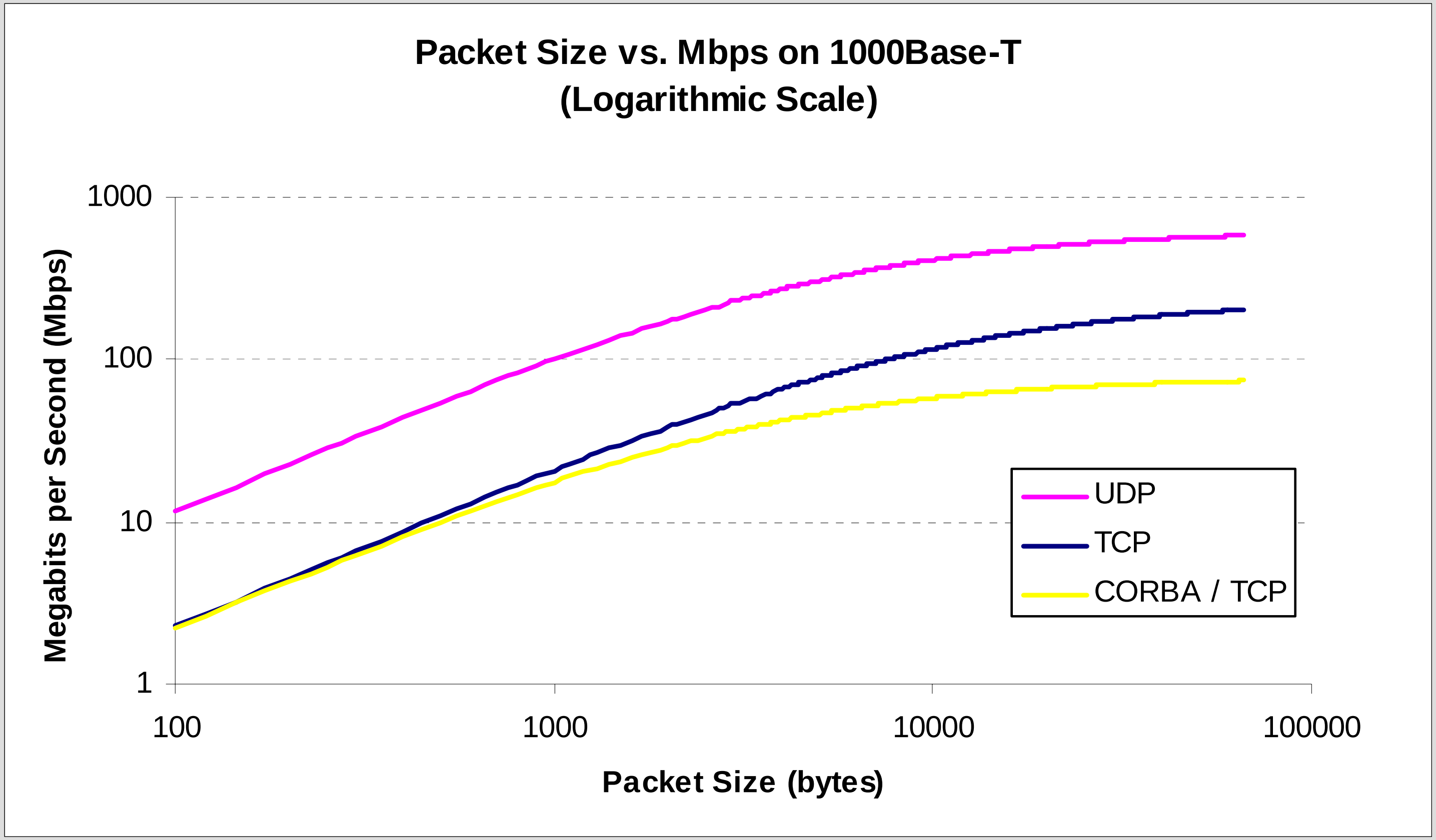
CORBA, TCP , UDP Data Rates - 1Gb Ethernet



UDP rates over 400 Mbps

TCP rates over 150 Mbps

CORBA rates over 70 Mbps

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Data Transfer Conclusions

Current bandwidth is sufficient for all MILSATCOM LDR, MDR, and XDR waveforms.

SCA architecture allows for growth over 400 Mbps using the current HW architecture.

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Ethernet / OmniORB Performance

- Quote from OmniOrb user group data:

- First, I tested the performance on a 100 and then 1000 Mbit point-to-point LAN between two computers.
  - Using the 100 Mbit LAN, I transferred nearly 75 Mbit on "user-data" each second.
  - if I use the 1000 Mbit LAN, I transferred only 150 Mbit each second.
  - If I use sockets, I reach 700 Mbit each seconds

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General Observation of Waveforms and CORBA

- More study needs to be done using high speed waveform applications to have a better understanding of the limiting factors of communication software at the application level (how the data is used)
  - Packet size and rates vs. streaming data
  - Periodic vs. aperiodic data that may have contention for backplane throughput
  - Burstiness of data (buffer management)
    - Data buffering (data need real time or processed off line)
  - Alternate methods to use multiple data channels
  - Data types (Voice, Video, Analog, Digital, or combination)
- Studies on how to improve waveform communication software
  - Lighter-weight protocols and other optimization techniques for non-SCA/non-CORBA data transfer between the NIU and WB REEM
  - UDP API for data transfer of RAW data or Compressed data
  - Some of these optimizations are being utilized in commercial network interfaces and operating systems where CORBA is combined with traditional sockets API to improve performance.

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Final Notes

- The Proof of Concept Demo showed that with the SCA and current HW architecture:
  - for the LDR/XDR waveforms, a reasonable performance can be achieved
    - Using a 1 Gb interface between NIU and WB REMM provides a margin for multiple waveforms.
    - Using a 100Mb interface will not provide growth needed for future high speed waveforms.
    - Further testing is needed for SCA user data and TRANSEC processing of periodic and aperiodic data.
  - for data rates above 50Mb / second
    - Reasonable performance may be achieved through alternate methods using TCP or UDP.
    - UDP within the a closed backplane can be managed to reliably support alternate data transfer methods.
    - Depending on whether the data is used point to point or within a network the NIU can bridge the downlink and buffer data to private networks using TCP as needed.

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