THE USE OF PTP IN FINANCIAL APPLICATIONS

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JUST A NORMAL DAY AT THE NATION'S MOST IMPORTANT FINANCIAL INSTITUTION...

WELCOME TO THE WORLD WHERE …
…TIME IS MONEY !

LATENCY is money…

Latency* is a measure of time delay experienced in a system, the precise definition of which depends on the system and the time being measured. Latencies may have different meaning in different contexts.

Source: wikipedia

AGENDA

Importance of time in Financial Trading

- Why is Financial Trading so sensitive to accurate time and latency ?

Latency monitoring

- Identification of latency sources

The role of PTP

- Accurate time delivery
- Latency monitoring

FINANCIAL MARKETS VALUE CHAIN
...AND THEIR SENSITIVITY TO LATENCY

Player
- Universal Banks
- Investment Banks
- Brokers
- Investment Companies
- Hedge Funds
- Fund Managers
- Insurance Companies
- Corporates
- Individuals
- Retail Brokers
- High Net Worth Individuals
- Pension Funds

Business Unit
- Wholesale Banking
- Commercial Lending
- Trade Finance
- Structured Finance
- Corporate Finance
- Asset Manager
- Brokerage
- Private Banking
- Private Equity

Access Channels

Customer Relationship Management

Front Office — Trading and Sales
- Trading Area
- Foreign Exchange
- Equity
- Fixed Income
- Money Markets
- Derivatives
- Commodities
- Mutual Funds
- Mergers and Acquisitions
- Trading Support
- Order Manage
- Order Routing
- Deal Capture
- Positions, Limits, Credit Control
- Dealer Analytics
- Investment Research

Middle Office
- Market Risk Management
- Credit Risk Management
- Operational Risk Management
- Management Analytics
- Profit / Loss

Back Office
- Operations
- Clearing
- Settlement
- Custody
- Trust
- Financial Control
- Compliance

Market Infrastructure
- Central Banks
- Regulators
- RTGS
- Exchanges
- Central Securities Depositories
- HVPS
- Swift, Cedel, Euroclear, Fedwire, CLS

Information Providers and Market Data

Enterprise wide risk data

Bank Infrastructure – IT, Property, Communications

Management, People, HR, Legal

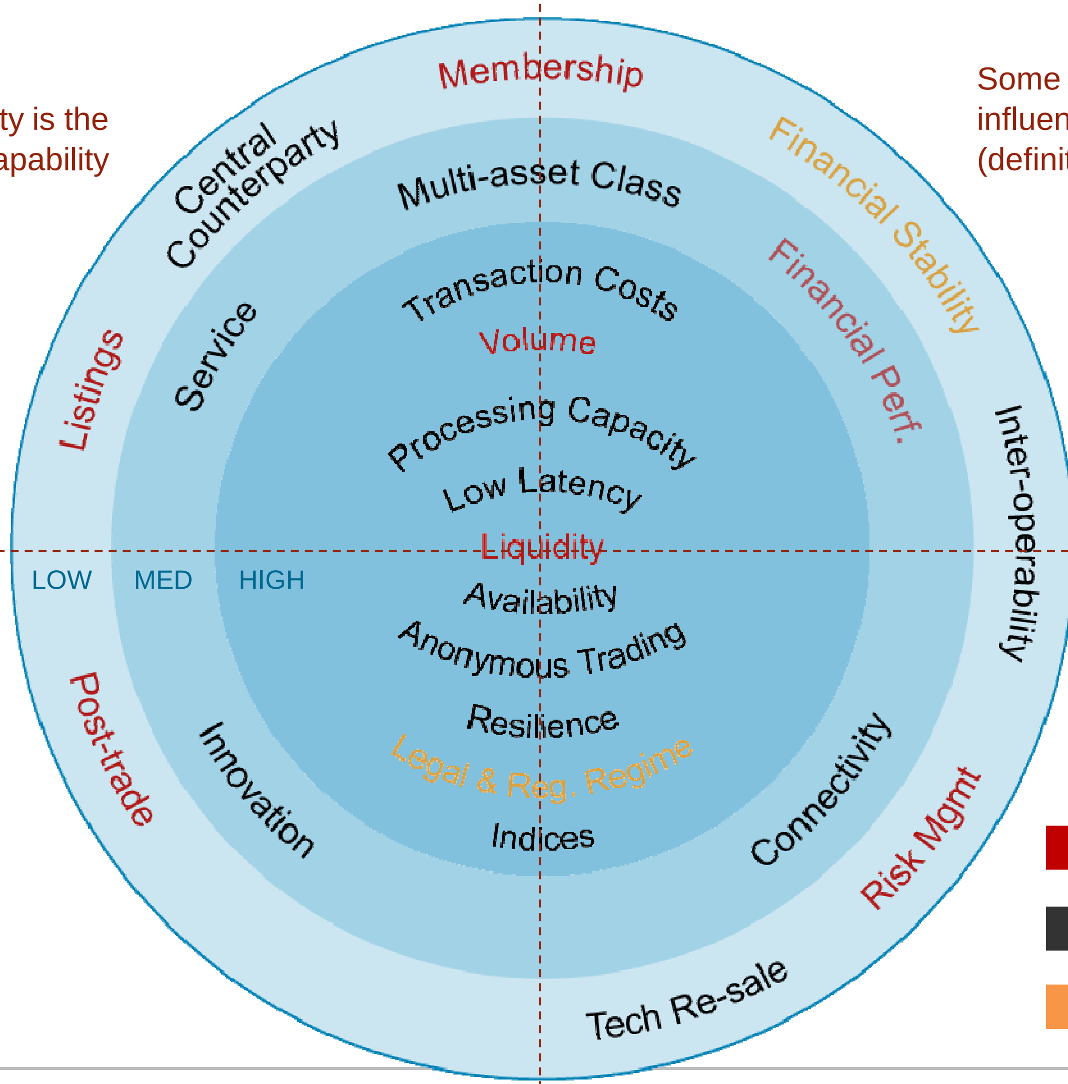
Key
- Latency Sensitive
- Outside
- Inside

KEY CAPABILITIES DEFINING AN EXCHANGE LATENCY IS AT THE HEART OF CONCERNS

Liquidity is the primary capability

Some capabilities can be influenced by an Exchange (definitions in App. C)

Relative Importance



Relative Importance

Exchange required capability

Can be controlled by an Exchange

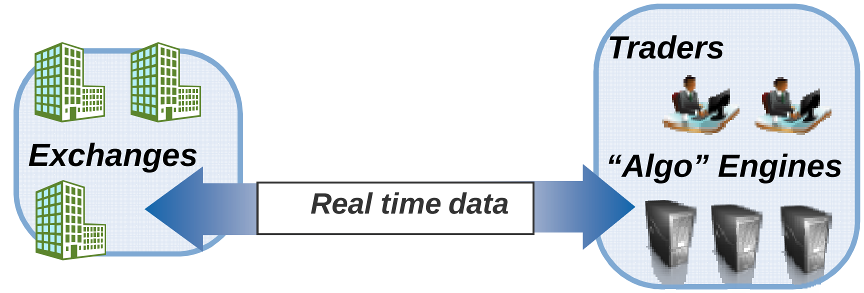
Can be heavily influenced by an Exchange

LOW LATENCY SCENARIOS

1. Market Data Distribution

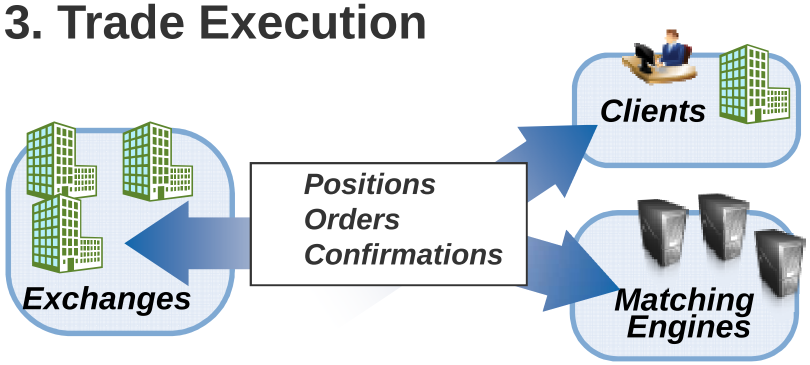
- *High throughput and fan-out distribution*
- *Managing message traffic including congestion, slow consumers, retransmissions, resources*

2. Human & Algorithmic Trading



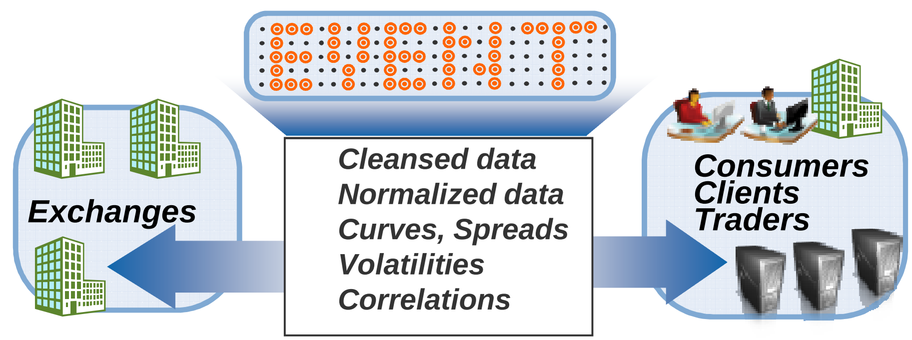
- *Transport market data from feeds to consuming traders and algorithmic trading apps and delivery of data to other trading locations for cross-market arbitrage*

3. Trade Execution



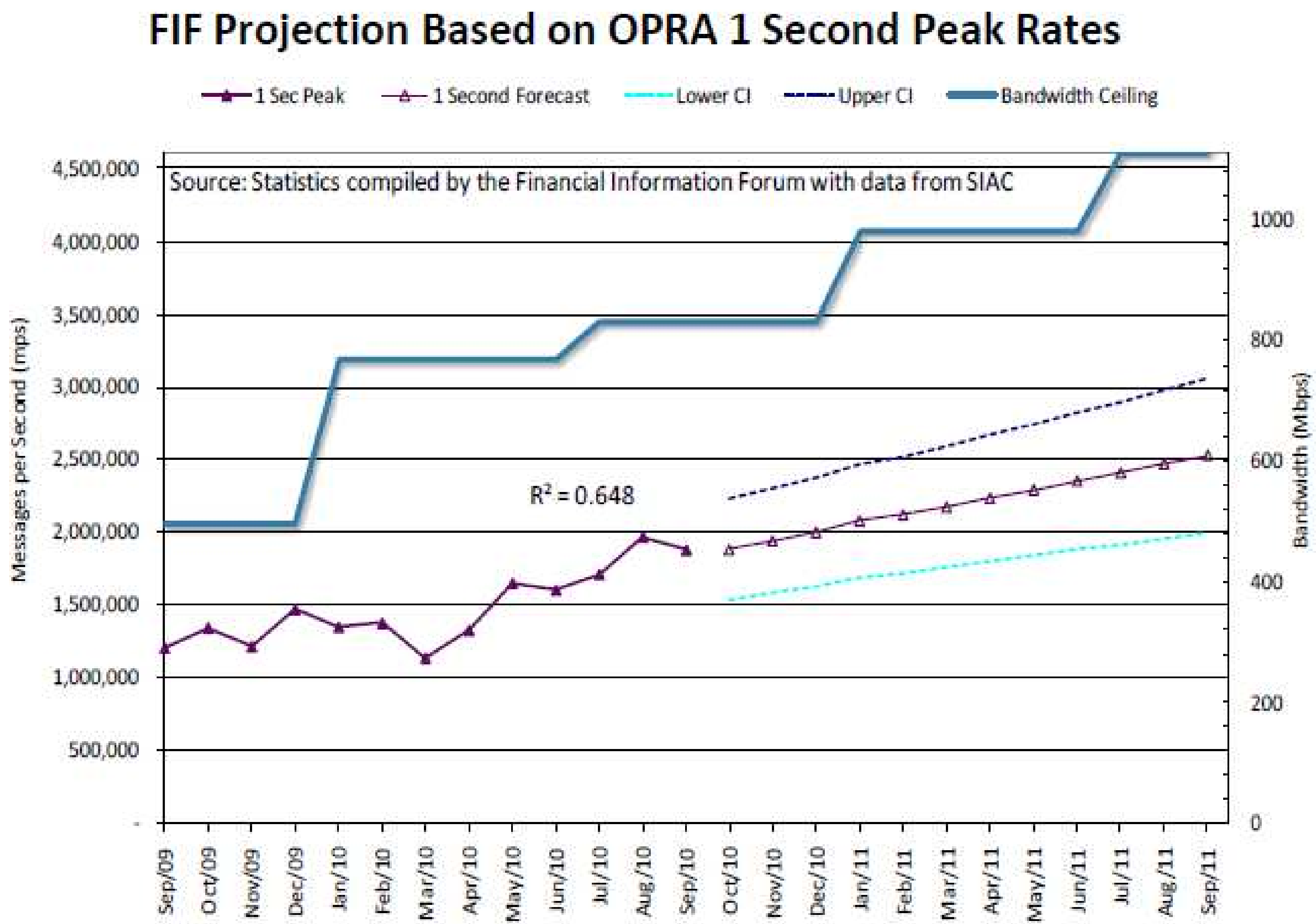
- *High throughput to handle spikes with fewer servers*
- *High availability for loss-less failover*
- *Auditable without compromising latency & throughput*
- *Sophisticated execution routing with advanced filtering*

4. Real-Time Surveillance



- *Real-time analytics with event notifications for systems monitoring, risk analytics and compliance applications*
- *Delivering filtered data for Complex Eve*

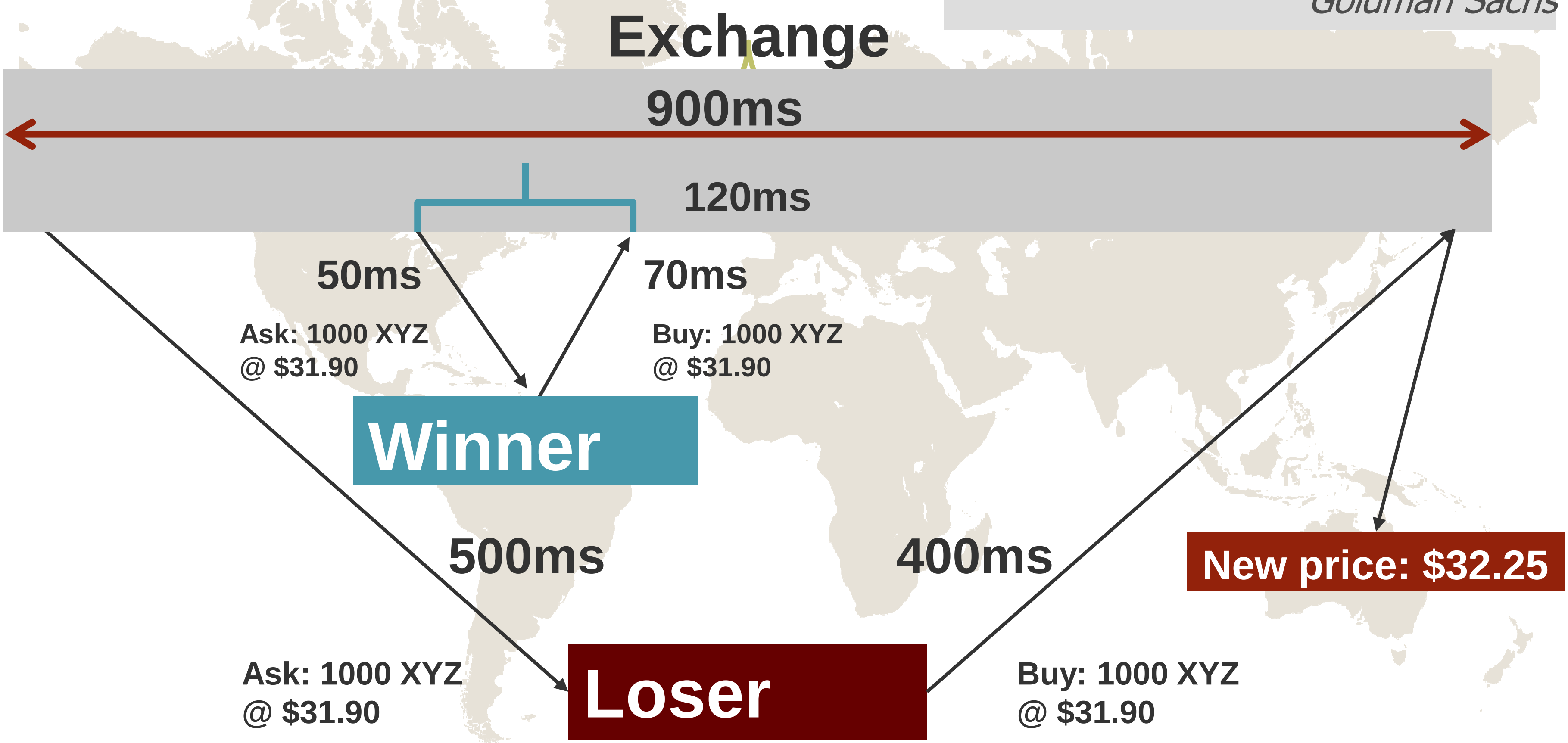
REASONS FOR PRESSURE ON LATENCY



OPRA : Options Price Reporting Authority

LATENCY IN ELECTRONIC TRADING

"Every Millisecond of latency eliminated equates to $100 million annually in revenue opportunity"
Goldman Sachs



Source: TradingMetrics, Inc. http://www.tradingmetrics.com/

ALGORITHMIC TRADING STRATEGIES EVERY MICROSECOND COUNTS

Algorithmic strategies deliver rapid analysis and response to market data

- Only rapid, low latency exchanges permit such high frequency trading
- Example of applications : Algorithmics (http://www.algorithmics.com)

Algorithmic trading is highly dependent on execution speed and market data availability <u>down to the millisecond</u>

Latency from publisher API to subscriber API

Message Rate	Mean Latency	Standard Deviation	99.9^{th} % Latency
500K / sec	25 us	6 us	41 us
1M / sec	28 us	6 us	48 us

ALGORITHMIC PROCESSING ENGINES

Robots / state machines: intelligent processing to gather real-time and historical data, analyze it in real time, take decisions, and place orders

Highly communicative: exchange messages across a distributed processing environment

- Take inputs, distribute processing, converge to a central decision point

Running in parallel

- Simulation of trades (duplication of trades, real time and non real time)
- Simulation of dis-engagement to reduce loss
- Impact of risk in decision (risk assessment)
- Impact of regulation (compliance)

HIGH PERFORMANCE COMPUTING
THE MULTICORE ARCHITECTURE CHALLENGE

The finance industry is challenged about using multicore architectures

- Hardware of all servers is consistent in a cluster
- Dedicate a core to an application: better control on application execution
- Scale it
  - 20-40 servers per POD (rack), 128 PODs per cluster: 5K servers per cluster
  - 8 cores per server: 40K cores per cluster - ALL IN PERFECT SYNC !

Accurate time delivery to the server

- External (coax to GPS/IRIG-B) or in-band (PTP OC) to the NIC (10GE)
- NIC delivers time to the Operating System and to the cores/thread
- Cores and network stacks ? Cores and PTP ?
- Time Monitoring ?

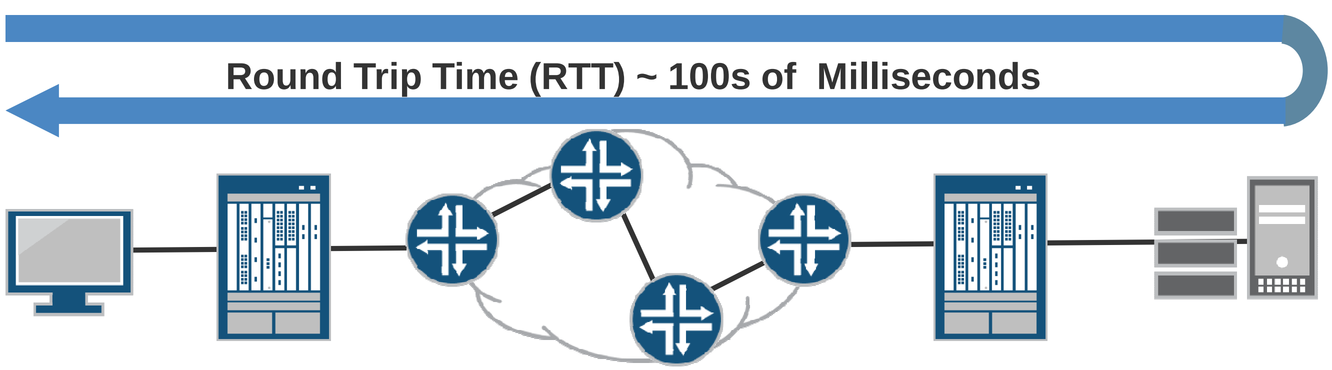
Syntonization of all cores in a server: Target = control execution time

- Detect deviation in CPU frequency, hence is planned execution time
- Extends to servers in a cluster and in a cloud
- Requirement: deliver frequency to servers

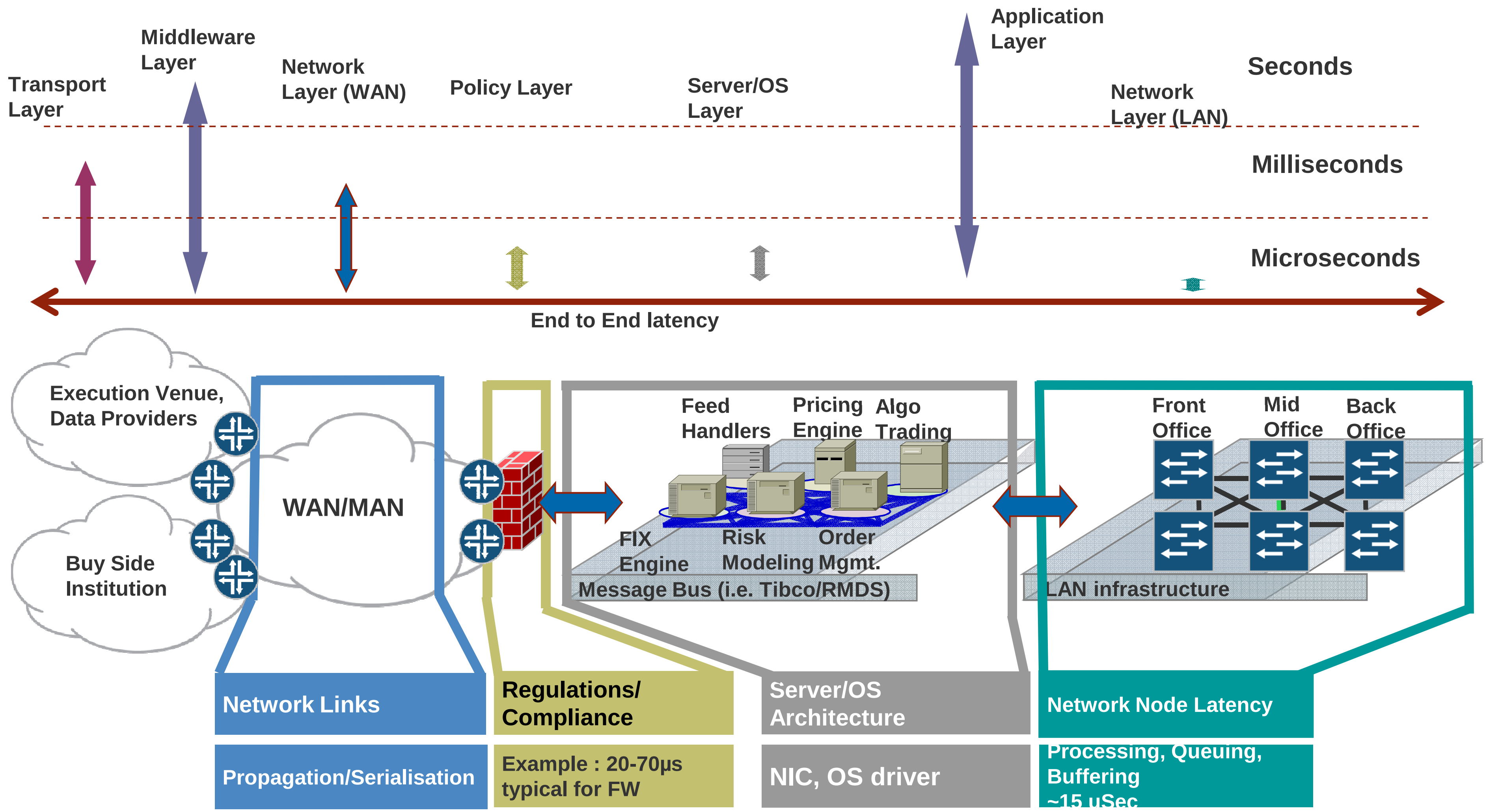
LATENCY MONITORING
LATENCY SOURCES OVERVIEW

Application performance is impacted by latency in several ways:

- **Network layer** (OSI layer 1-3): the amount of time necessary for a message to traverse the network elements (propagation, serialization, router/switch processing and queuing)
- **Transport layer** : the amount of time necessary for the transport mechanism (TCP/UDP) to acknowledge and retransmit data
- **Middleware layer**: efficiency of the messaging bus in delivery and recovery of market data and transactions
- **Application Architecture** : the overall application architecture choices will affect latency (such as Database structures, locations etc.)
- **Server/OS Architecture** : time for local application requests to be fulfilled, including disk read/write, memory allocation, CPU, NIC processing etc.
- **Regulations/Compliance processing** : such as firewalls, load balancing, NAT, event monitoring/logging, encryption, Identity services, IPS, HIPS, virus protection etc.



LATENCY MONITORING
HOW DO THEY ALL COMPARE?



Many variables involved – key is to build a real time latency map

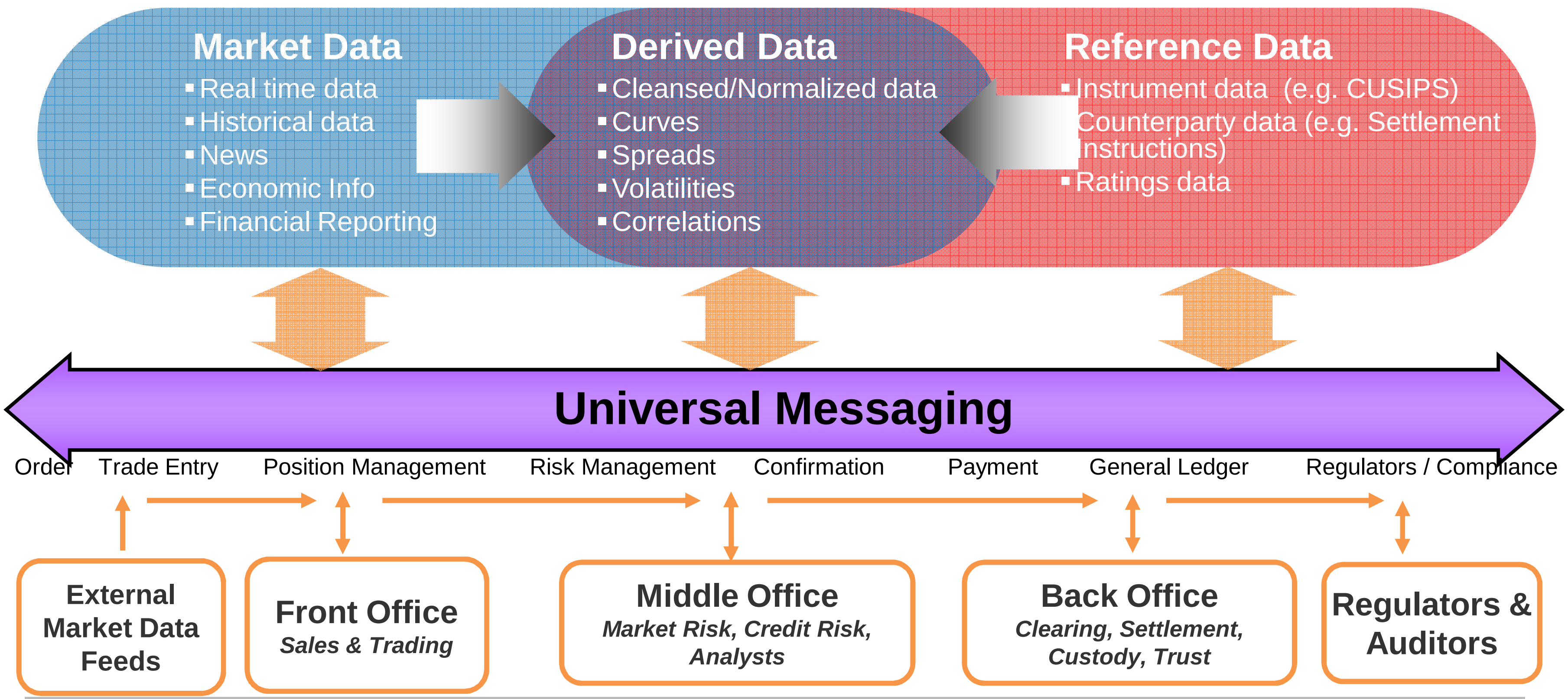
LATENCY MONITORING
QUANTIFY LATENCY SOURCES, APPLY SOLUTIONS

	Sources of Latency	Solutions
Regulations/ Compliance	Firewalls, load balancing, NAT, regularity monitoring/logging, encryption, Identity services, IPS, HIPS, virus protection	Hardware Assisted functions; Out of Band processing
Server/OS Architecture	Application Hardware (including Disk, CPU, Memory, Storage, NIC) and Operating System (Windows, Linux etc.)	Hardware Assisted functions (RDMA, In-Memory Caching, TCP offload, FPGA, xNIC etc.); Grid/ HPC; SAN; Application Optimized Systems; Infini-band; OS tuning; Multicast
Application Architecture	Presentation, application and session layer Design and interdependencies, Loosely vs tightly coupled, Proprietary vs COTS	Real time feed / DMA; SOA; Hardware Assisted functions; Network friendly applications; Open Source; Flat client side dist. Parallel processing
Middleware Layer	Middleware protocol characteristics such as messaging overhead, retransmissions, setup, tear down etc. (includes FIX, FAST, Tibco/RV, RMDS/RRCP, LBM, AMPQ, HTTP etc.)	Compression (FAST); Transparent protocol acceleration; Protocol optimization/tuning (High speed message bus); Multicast
Transport Layer	TCP Protocol Overhead; UDP Buffering; Packet loss/RTT/out of order/ fragmentation	Direct TCP Optimization (buffer size, window size, Nagle, rfc1323, rfc3390 etc.); Transparent TCP/UDP acceleration
Network Layer	IP, Router/Switch Processing, Congestion/Queuing, Microburst's; Physical Layer (Ethernet, WAN etc.), Serialization, Propagation	Congestion control - QoS Policy; Low Latency Ethernet 10GE; Application based throttling; HW switching/ acceleration; Proximity services Review SP services

FINANCIAL MARKET DATA INTEGRATION TRENDS

Boundaries blurring between where market data platform & trading platform

Greater need than ever for integration between front-, mid- & back offices



TIME DISTRIBUTION AND MONITORING CHALLENGES

Time source

- U.S. Naval Observatory (USNO) and the National Institute of Standards and Technology (NIST) are legally certified time stamping services

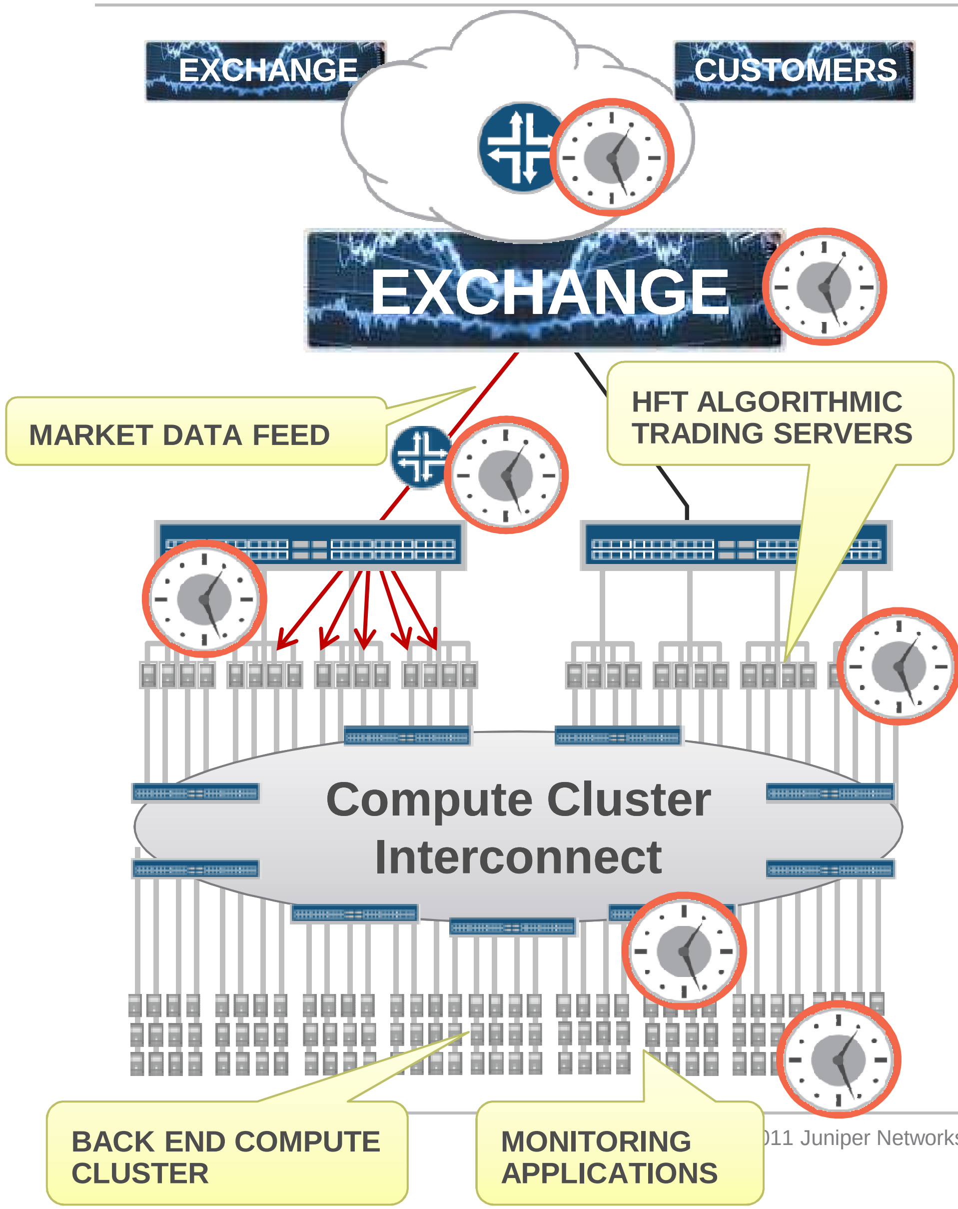
Delivery

- GPS, delivered directly or using IRIG-B, through distribution panels
  - Cable length / paths managed carefully / manually
  - Redundancy using 2 or 3 feeds in large DCs, but only 1 in small DCs
- NTP
- PTP
- Delivery issues
  - GPS typical issues (political, vulnerabilities, LOS, calibration)
  - Deployment cost and velocity

Monitoring

- External devices with coax cables plugging into servers
- Mirroring and tunneling to timestamping engines to application analysis engines (regulatory, etc)
- Monitoring issues
  - Expensive: huge cost (CAPEX, OPEX)
  - Complex: plenty of devices to deploy, manage, plenty of specific information types

RACE TO LATENCY
WHAT WE CAN IMPROVE IN THE NETWORK



Active components
- Active PTP in network nodes
  - WAN (routers)
  - LAN (cluster fabric)
- PTP in the servers (NICs, cores)
- syncE to syntonize PTP and servers CPU's
- Distributed latency monitoring

At high bandwidth
- Optical Fiber
- 10GE NICs
- Terabits/s cluster fabric (100GE)
- 10GE WAN links

At scale
- 6,000 servers per cluster, 40K cores
- 10's of network nodes in an exchange and between exchanges/customers

STAC SECURITIES TECHNOLOGY ANALYSIS CENTER

TEST RESULTS

Simulates Trading Transactional Performance

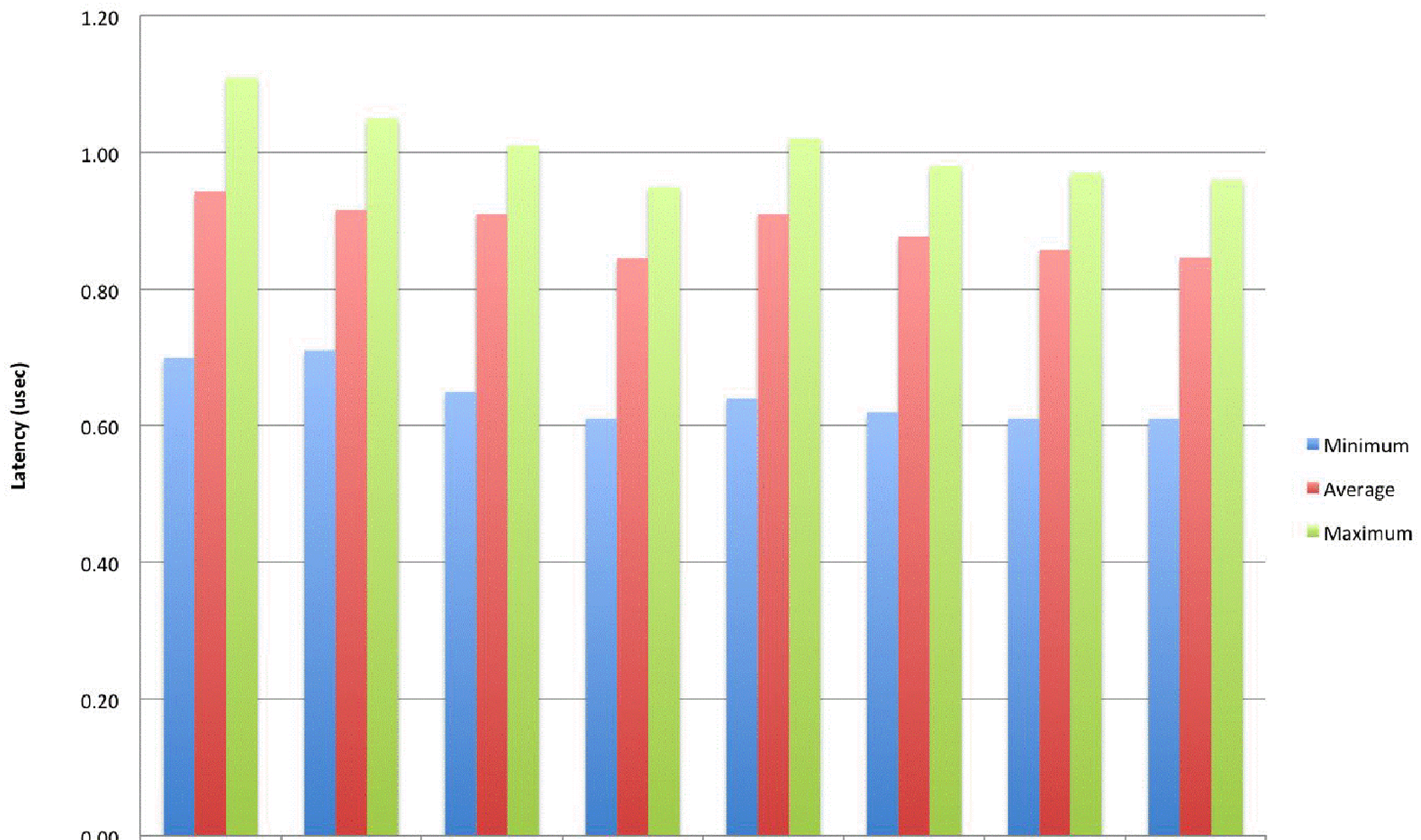
Description Supply to Receive Latency, 1 Producer to 5	**Juniper QFX3500/ IBM LLM**	**Cisco 4900M/29West**	**Cisco Nexus 5010/29West**	**Voltaire IB/IBM LLM**
Highest Supply Rate (msg/sec)	**1,500,000**	1,300,000	1,300,000	1,000,000
Mean (micro seconds)	**9**	15	14	8
Max (micro seconds)	**16**	30	33	47
Standard Deviation	**0**	1	1	1

The Juniper QFX3500 in combination with IBM server and middleware with SolarFlare NICs delivered the best performance to date for product combinations with 10GE switches.

This product combination delivered more messages faster with lower jitter than any other audited report in the STAC library.

Juniper NETWORKS

LATENCY AND JITTER IN THE NEW CLUSTER



	64	128	256	512	1,024	1,280	1,518	9,216
Minimum	0.70	0.71	0.65	0.61	0.64	0.62	0.61	0.61
Average	0.94	0.92	0.91	0.85	0.91	0.88	0.86	0.85
Maximum	1.11	1.05	1.01	0.95	1.02	0.98	0.97	0.96

SUMMARY

The Financial market is currently focusing on latency improvements

- Very dynamic environment, quick investment decisions

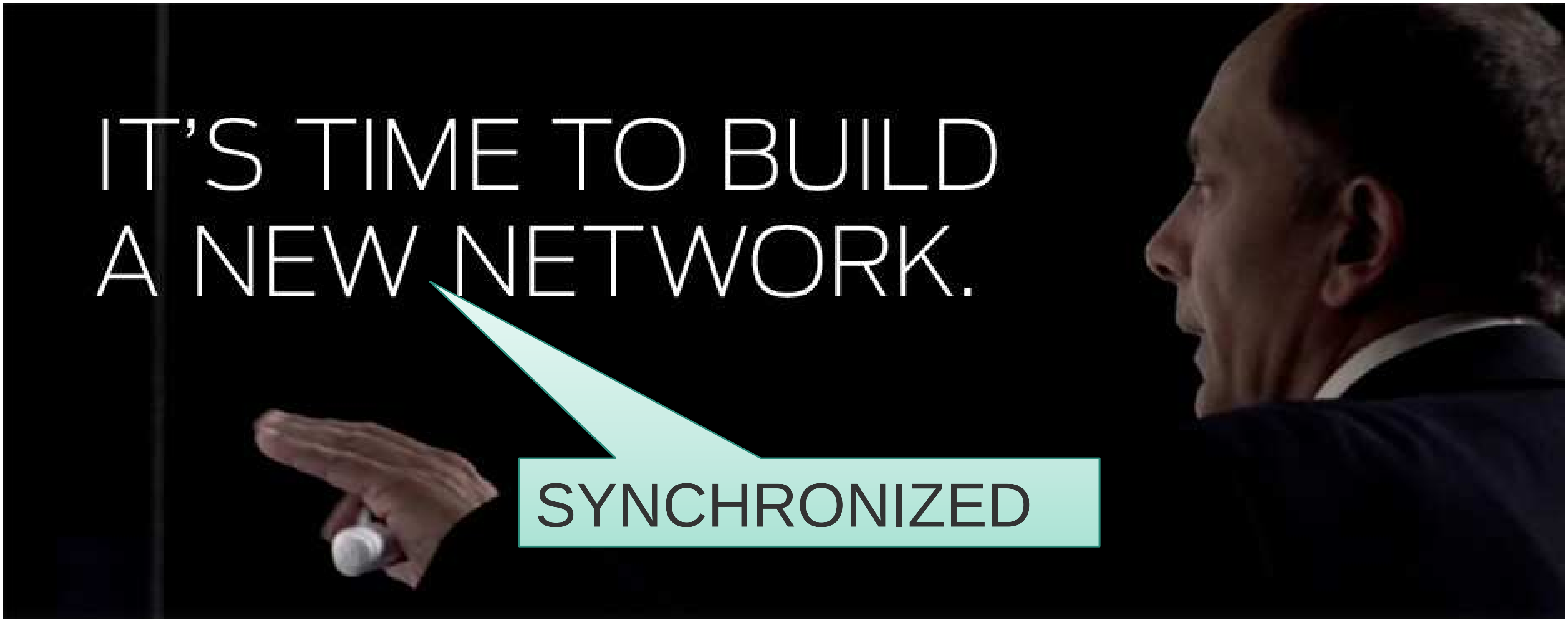
Essential components are

- Accurate time delivery
- Latency monitoring

PTP has a key role to play

- How far can we go ?

SETTING THE AGENDA FOR THE NEXT DECADE



Juniper Networks is transforming the
experience and economics of *synchronized* networking