LabVIEW Developer Days

Build Code. Form Communities. Gain Confidence.

NATIONAL INSTRUMENTS™

Data Communication for Scalable Systems

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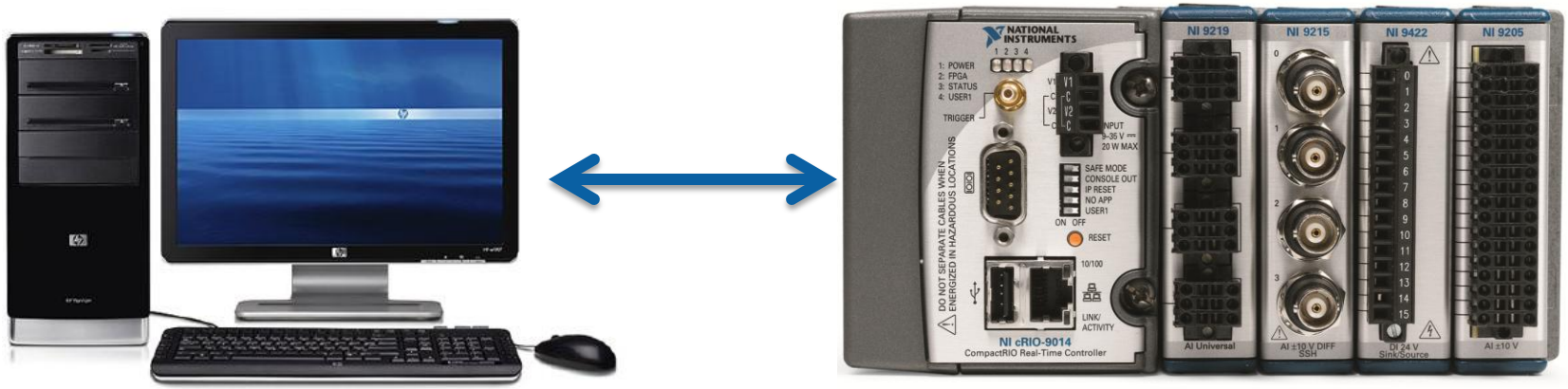
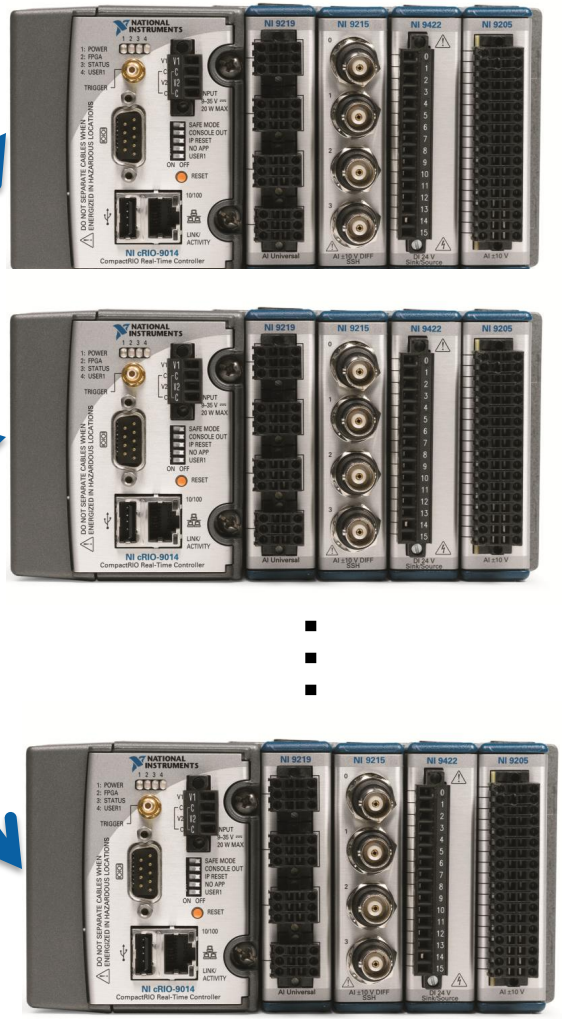
Session Goals

- Discuss common architectures to address scalability in embedded systems
- We will not discuss the basics of each type of data communication mechanism (what is TCP, what is a queue, etc)
  - For more information on the basics, see the LabVIEW for CompactRIO Developer's Guide (ni.com/compactriodevguide)
- We will discuss the tradeoffs of different mechanisms – when to use one over another

Why is Scalability Important?



Why is Scalability Important?



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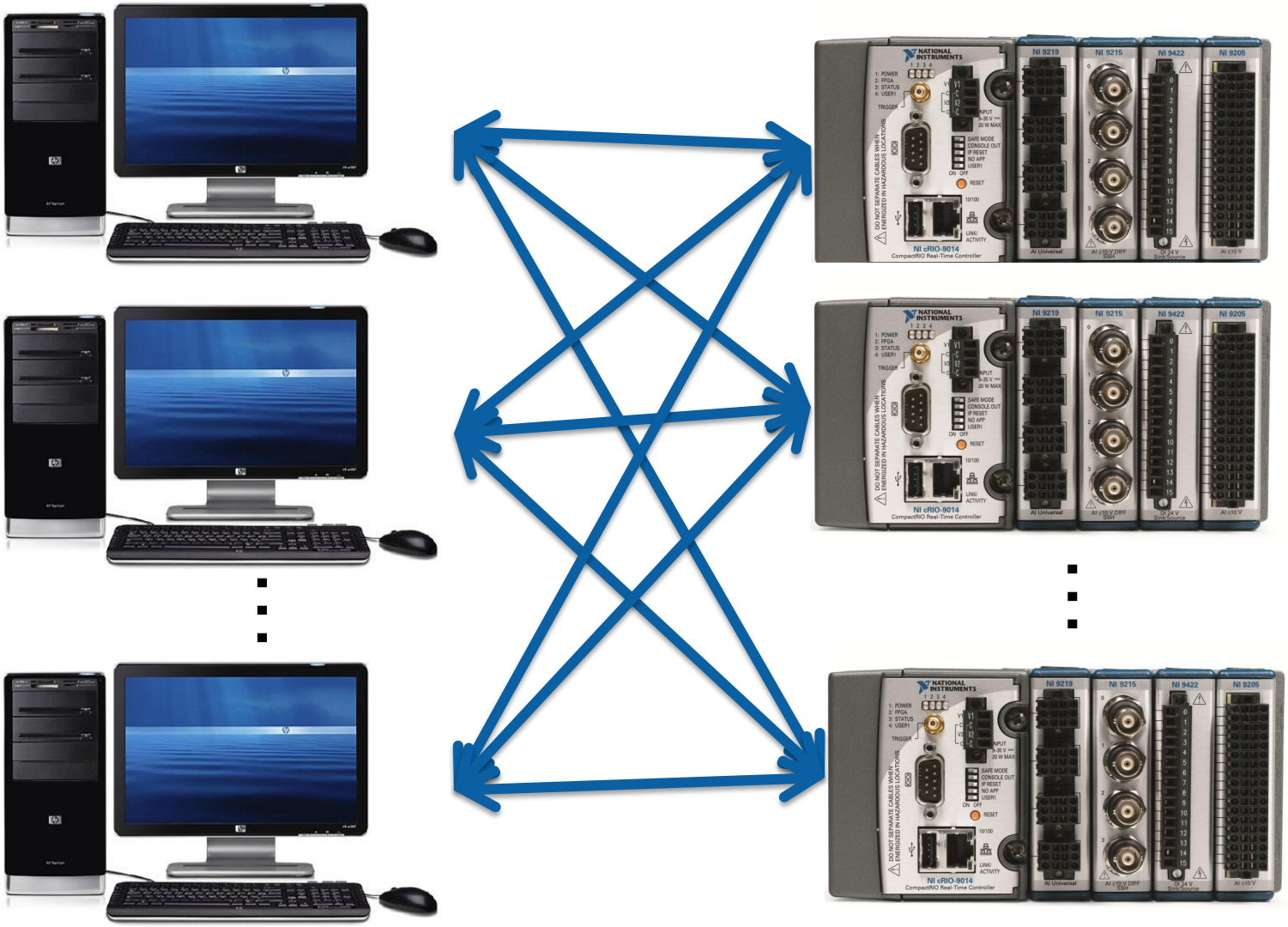


Goal of Scalability

Minimize added work and risk of adding ‘one more’

Scalability Strategies

- Use flexible communication schemes that minimize foreknowledge on the systems
  - No hard coded addresses if possible
- Use communication pipes that are optimized for the type of communication necessary
  - You probably need more than one.
  - If all you have is a hammer…
- Architect the system such that communications performance has minimal impact on critical operations

Available Data Communication Mechanisms

TCP and UDP
Network Streams
Shared Variables x 3
DMAs
Actor Framework
Peer-to-Peer Streaming
Queues
Dynamic Events
Functional Global Variables
RT FIFOs
Datasocket
Local Variables
VI Server

Target-scoped FIFOs
Notifier
Simple TCP/IP Messaging (STM)
AMC
HTTP
FTP
DVR
Web Services
ZMQ
AMQP
DDS
….
Many more

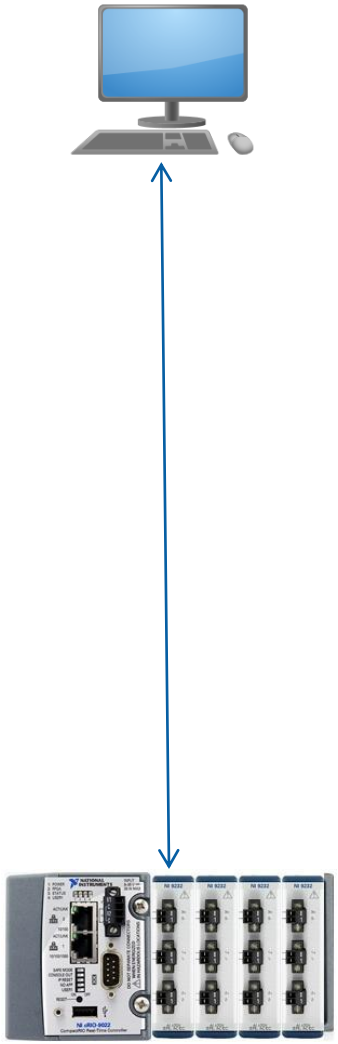
Data Communication Types

Tag *Current value data*

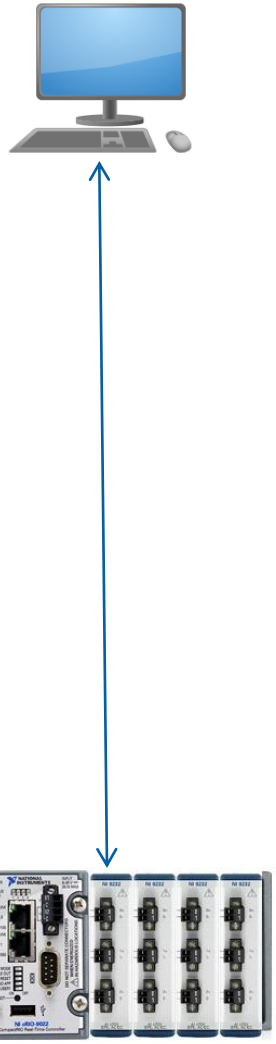
Messages/Commands *Intermittent data, reliable delivery*

Stream *Continuous acquisition, high throughput*

Single-Node Architecture



Single-Node Architecture



Great for 1:1
Focus on scalability: low to none
Functionality is usually first concern

Applications:
Prototypes
Simple control and monitoring

Potential concerns:
Easy replacement of either client or node

Headless Control System

Arbitrary computer
Zero-install requirement
Any operating system
Need to quickly attach to a maintenance interface

HTTP

Hosted web page
Web Services

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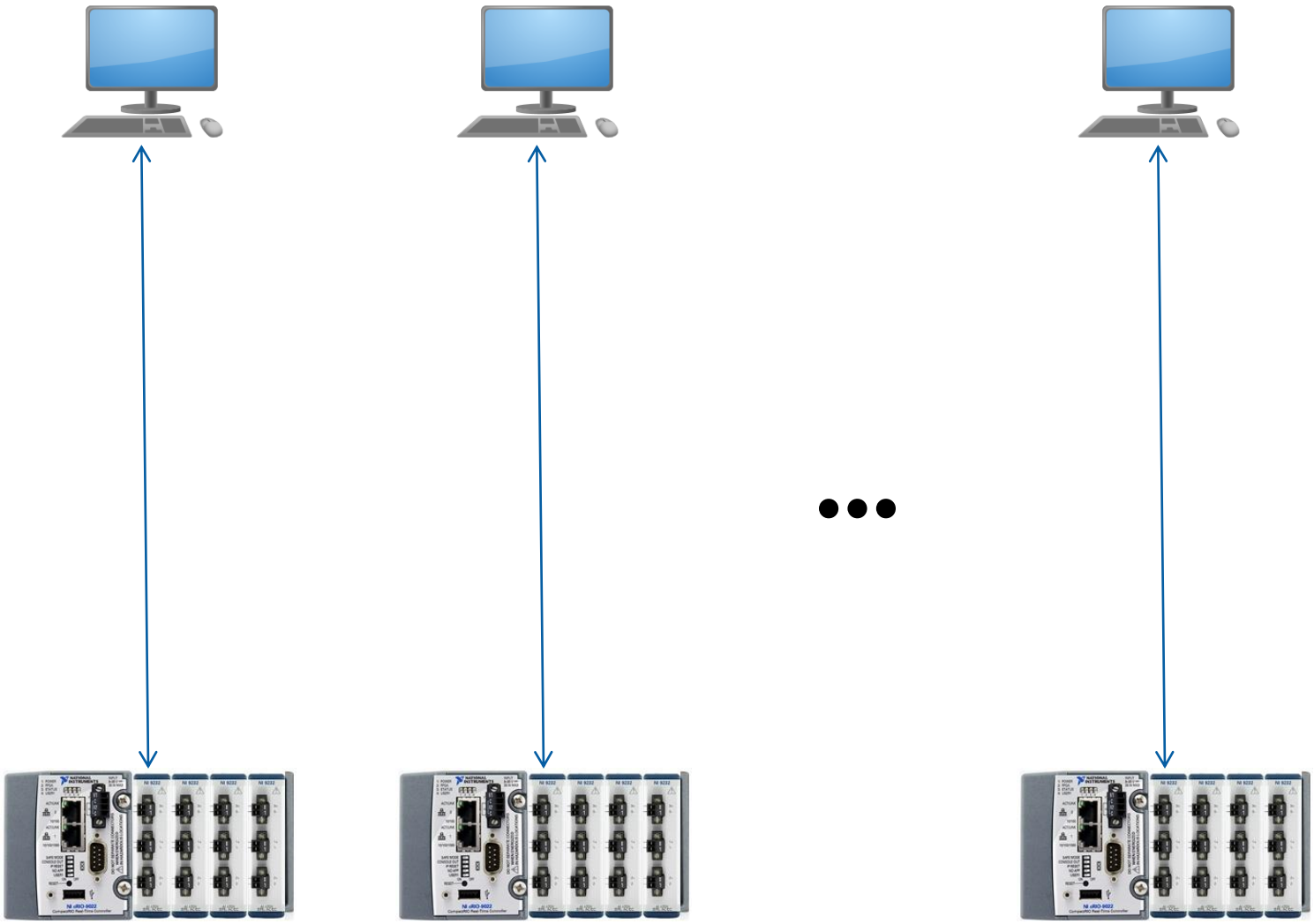
Embedded Datalogger

LV Client
Stream endpoint known in advance
Connects to one node at a time

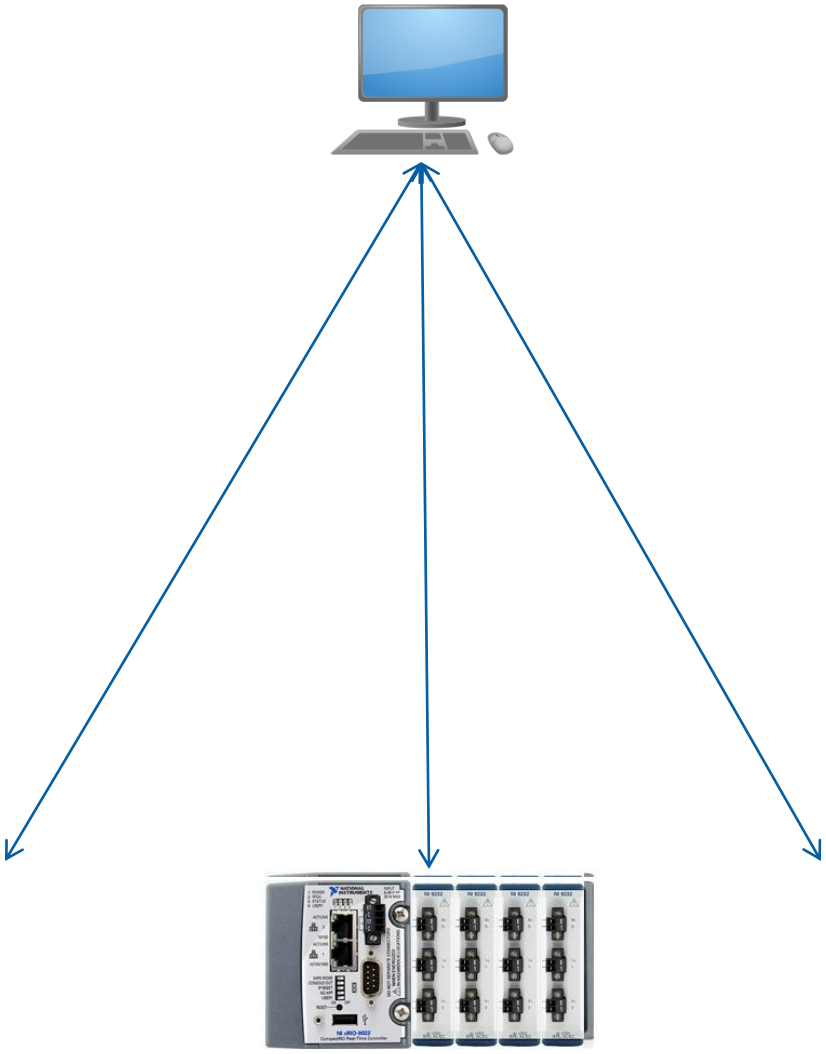
Shared variables for status
Network stream to node for commands
Network stream to client for waveform monitoring
FTP/WebDAV for file transfer

Shared Variable Engine hosts status tags
Streams connect to one HMI at a time

Replication



Multi-Node Architecture



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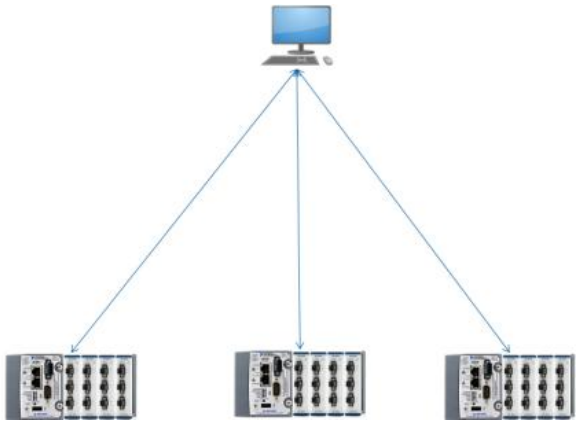


Scalability focus: Client code

Applications:
Multiple instances of identical nodes to one client
Low (often fixed) number of nodes

How hard is it to add one more?
- Node code: Little to no effort
- Client code: Medium effort

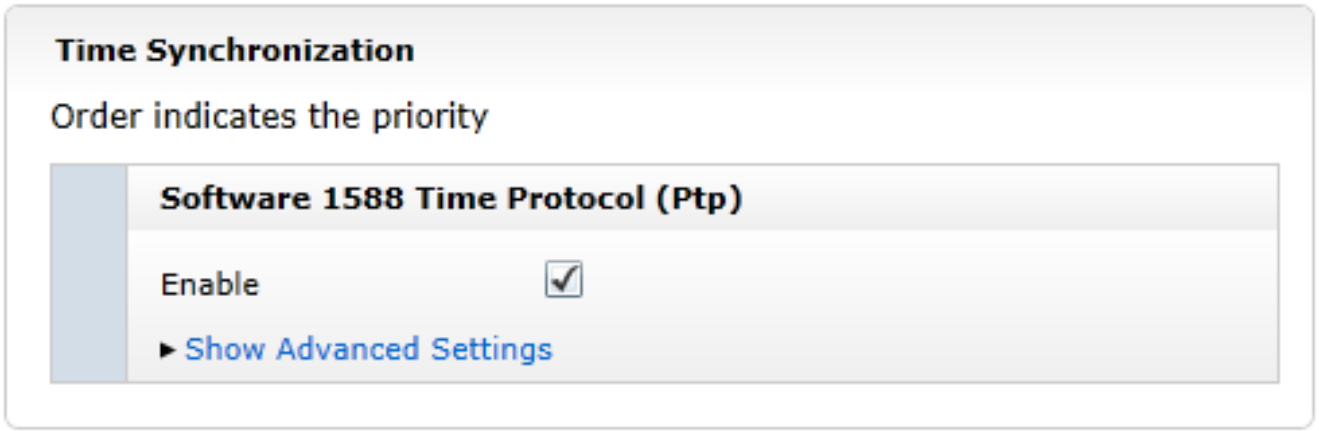
Potential concerns:
- Synchronization of timestamps
- Repurposing HMI screens
- Unique Network Stream endpoint names

Timestamp Synchronization

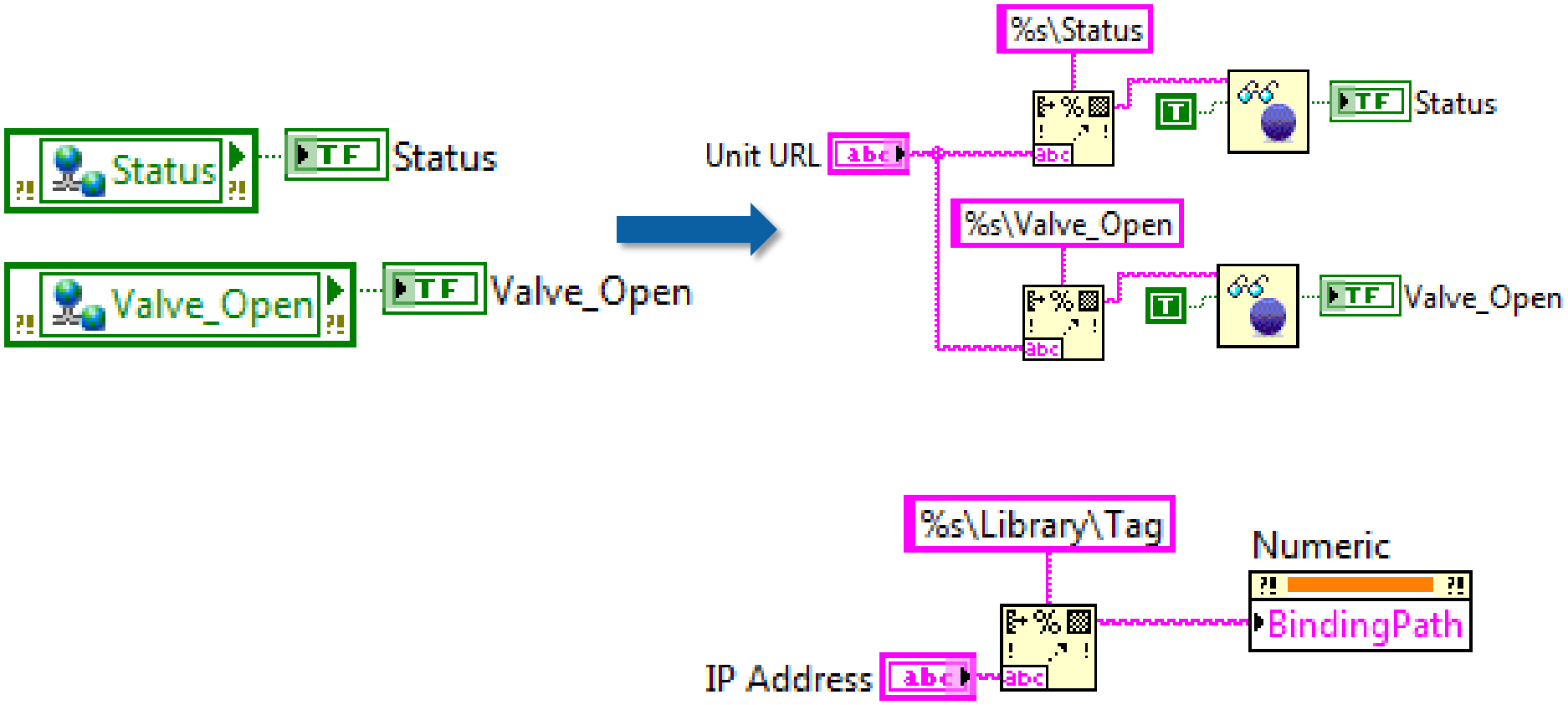


Timestamp Synchronization

- Software: IEEE-1588 Precision Time Protocol
- Installable component for NI RT targets via MAX
- Automatic, no fixed server need be configured
- Nodes on network auto-negotiate, set system time
- For best results, have one node on network synched to an accurate time source (e.g., GPS, hardware 1588, etc)



Reuse HMI Screens

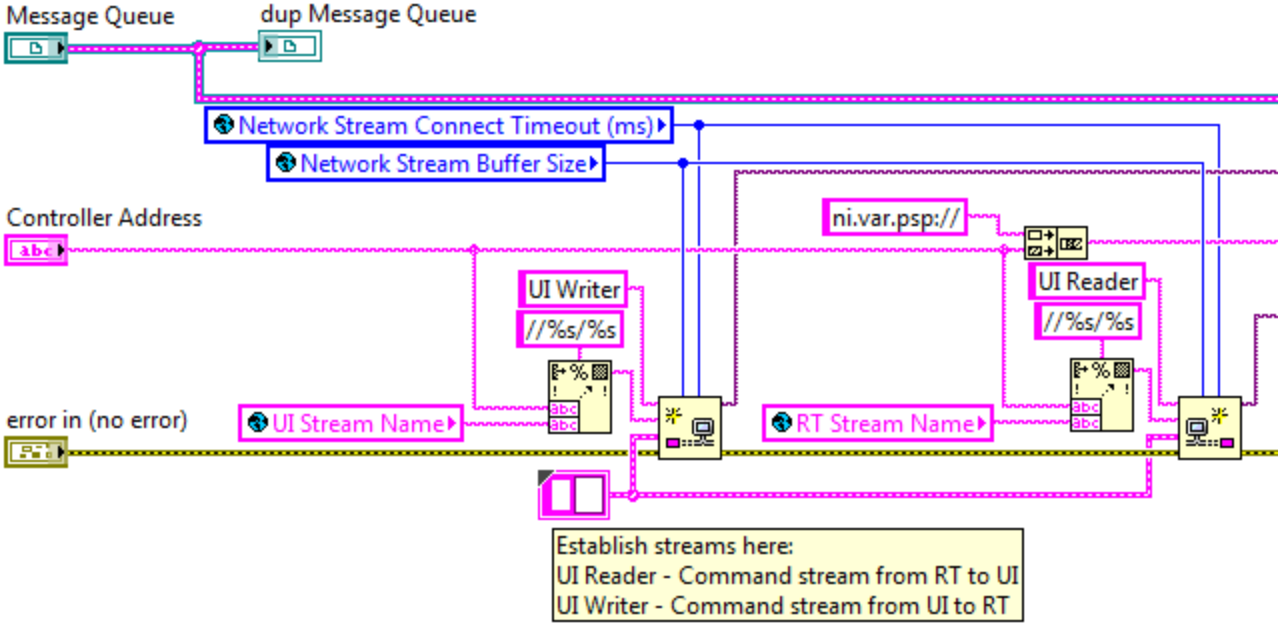


Network Stream Connection Bootstrapping

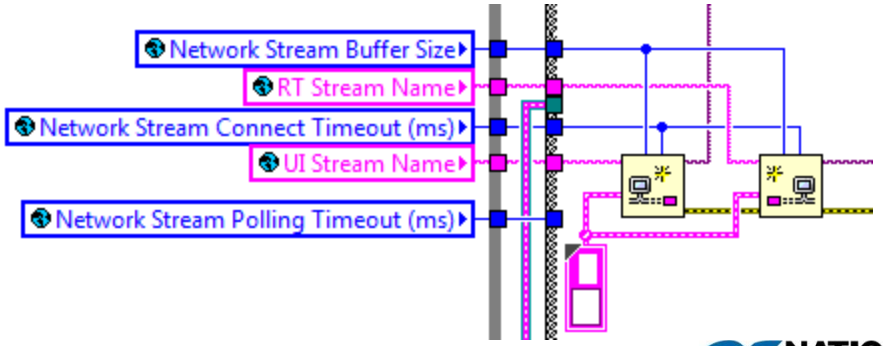
- Network streams are (by design) a 1:1 communication pipe
  - Exactly 1 writer and 1 reader endpoint per stream
  - Endpoint URLs cannot be reused amongst several streams
  - Easiest solution is to hard-code a URL for each node
- To scale, another layer is necessary

Single-Node Network Stream Connection

UI:



RT:



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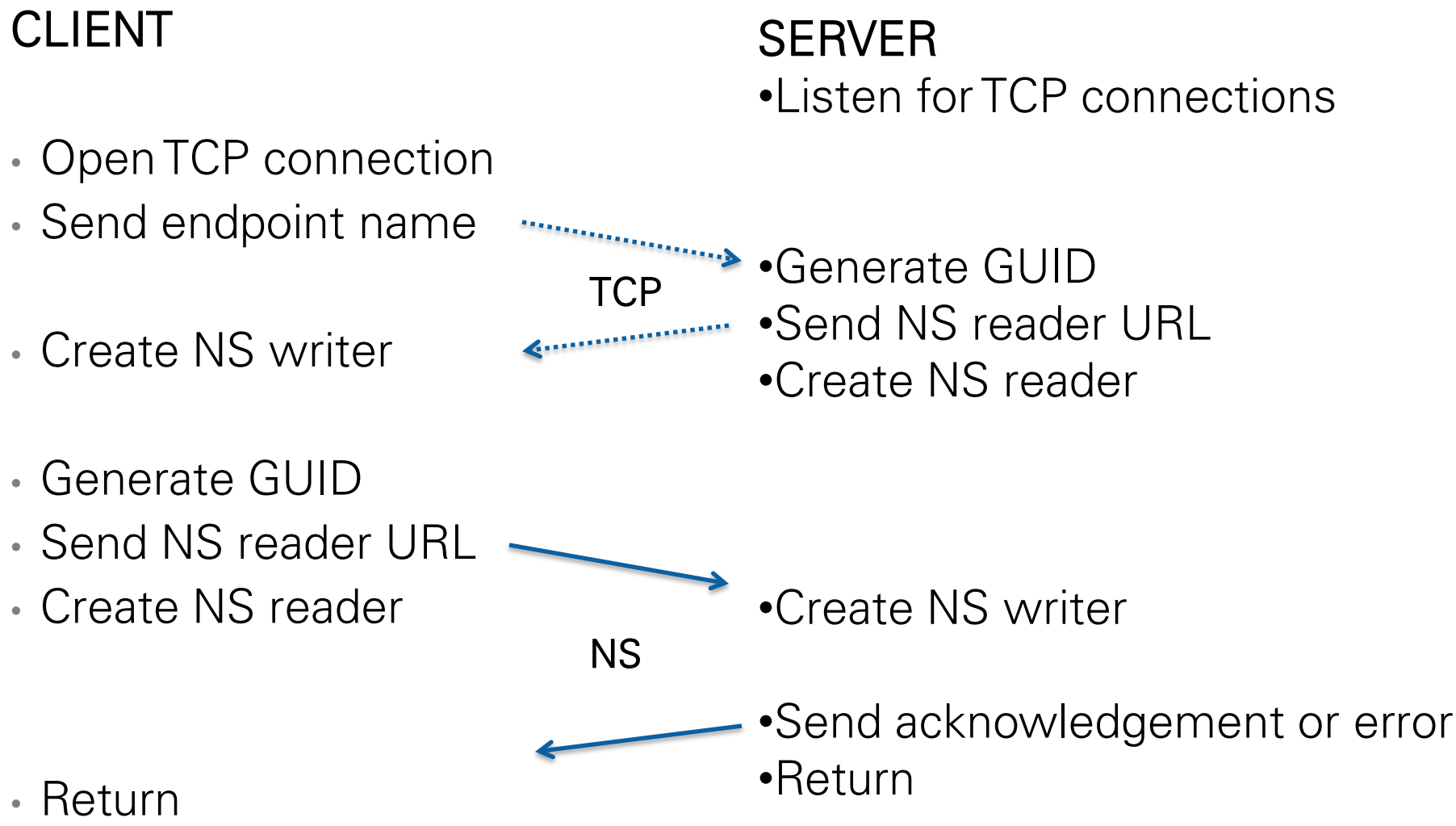
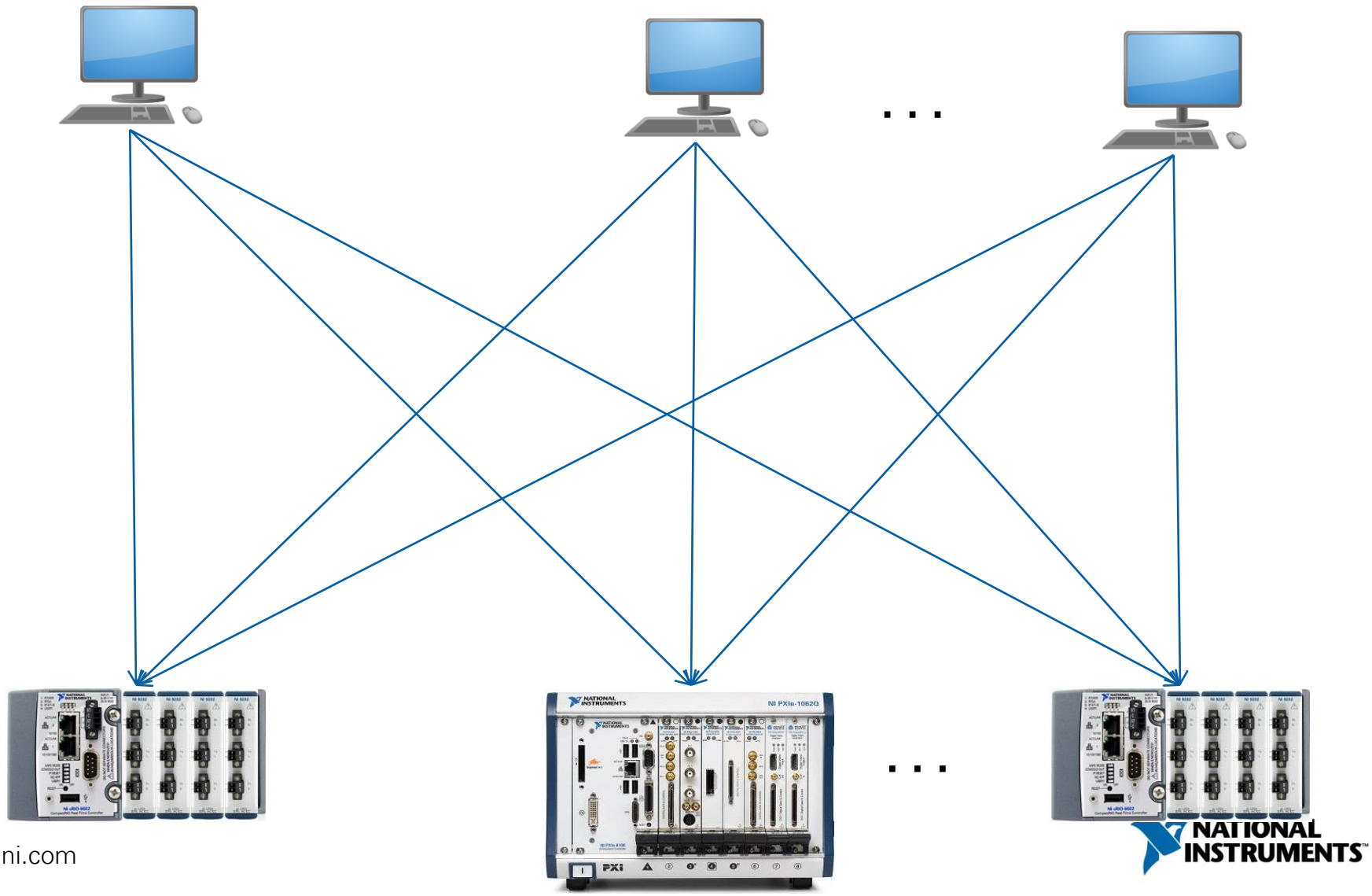


Serverless Architecture



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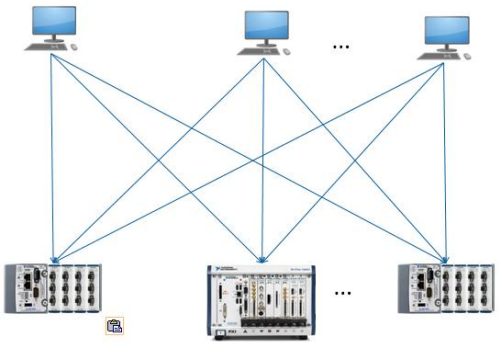
Serverless Architecture



Scalability focus: Node code and client code

Applications:
Multiple monitoring stations for complex system
Single station in control of any given node

How hard is it to add one more?
- Node code: Medium effort
- Client code: Medium effort

Potential new concerns:
- Load on nodes due to client access

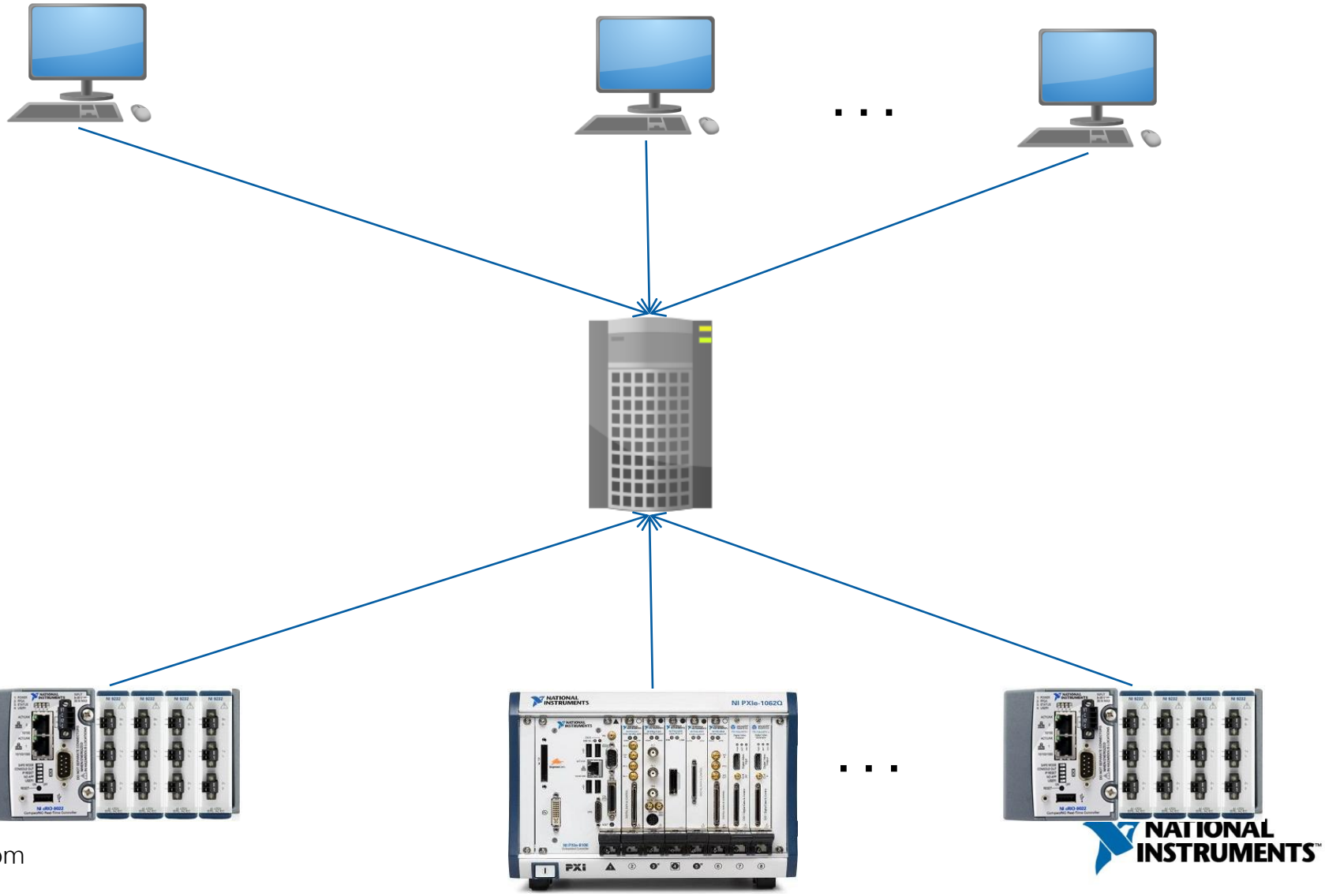
The Sweet Spot for Shared Variables

- Great for current value (tag) monitoring
- Originally intended for the SCADA use case
- Latest value (no buffering), scalar data
- Libraries of 500 variables or less
  - Break up larger libraries into multiple smaller ones
- SCADA data rates (<100 Hz)
- Sparse updates
  - Not everything updated at once every time
- Sparse subscriptions
  - Not every client looking at every variable every time

Scalability Red Flags with Shared Variables

- Shared Variables are not designed for commands or streams.
  - They are a lossy communication mechanism
    - Sending an emergency stop message via Shared Variable is unwise
- Shared Variables work best at SCADA rates (.1-10s of Hz)
  - Pushing streaming data at 1 MB/Sec through a Shared Variable is unwise
  - Use a Network Stream instead
- Load on Shared Variable Engine scales linearly with number of subscribers and frequency of updates
- Tool exists to benchmark performance on your system
  - Search ni.com for 'Shared Variable Benchmark Utility'

Single-Server Architecture



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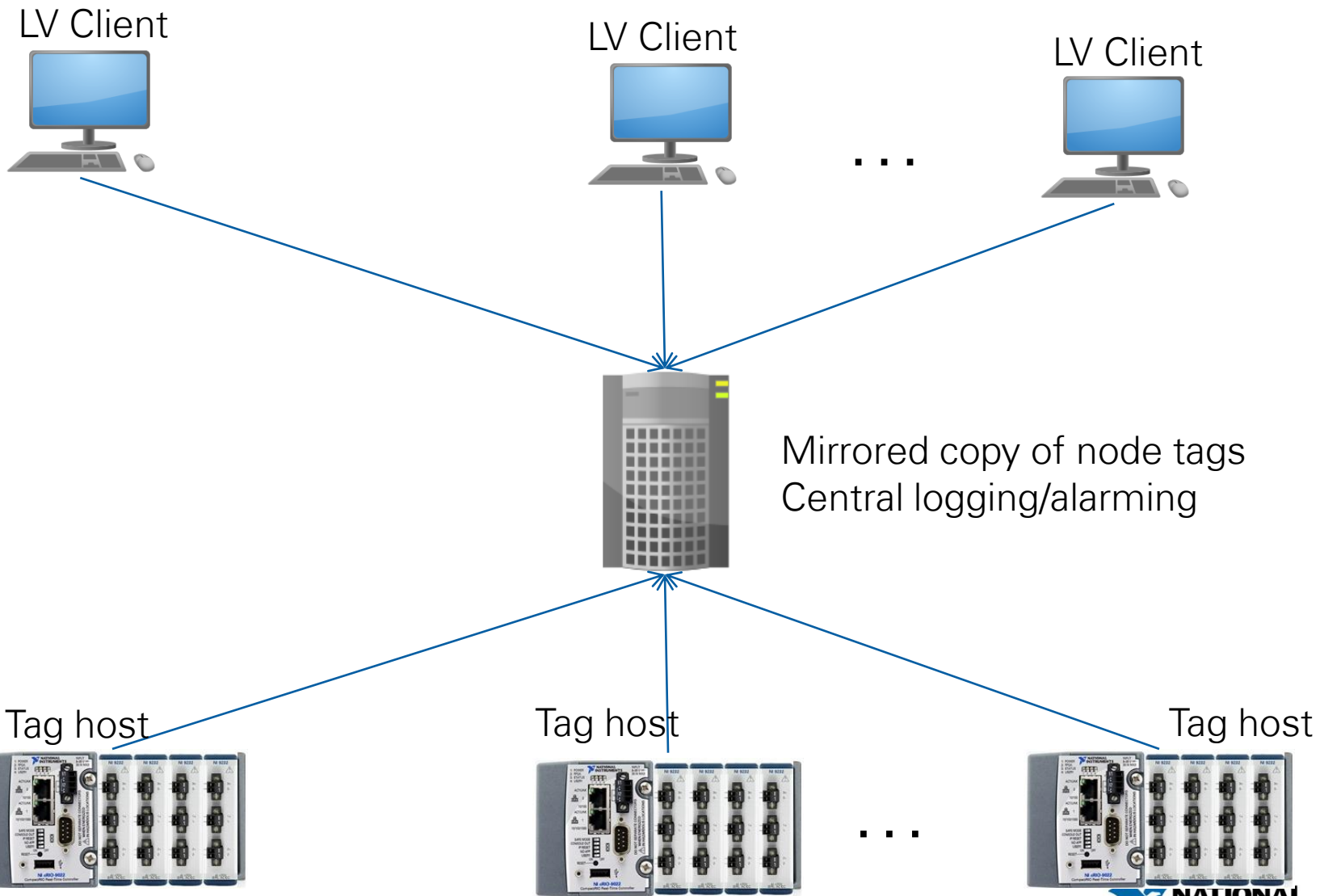
SCADA Use Case



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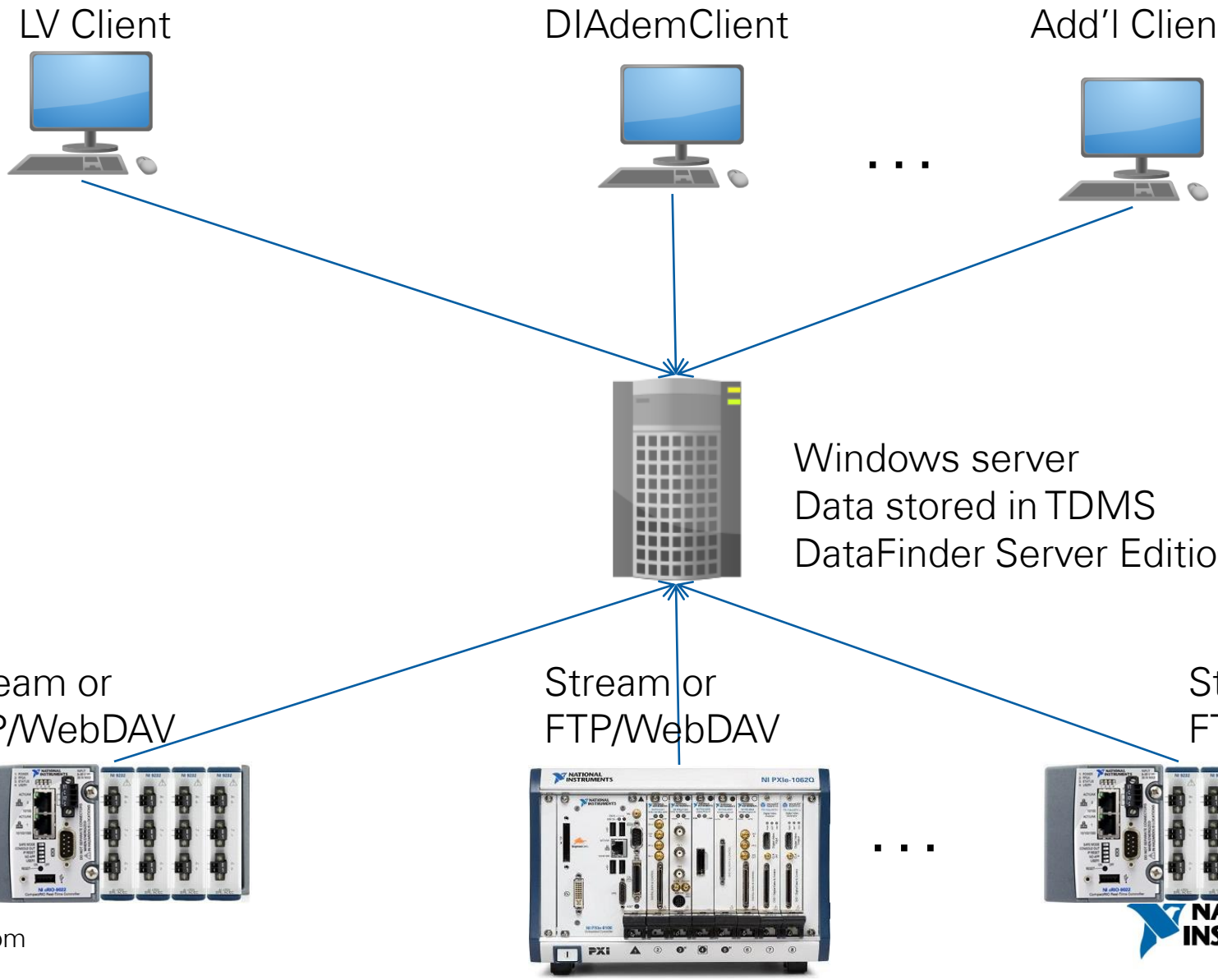
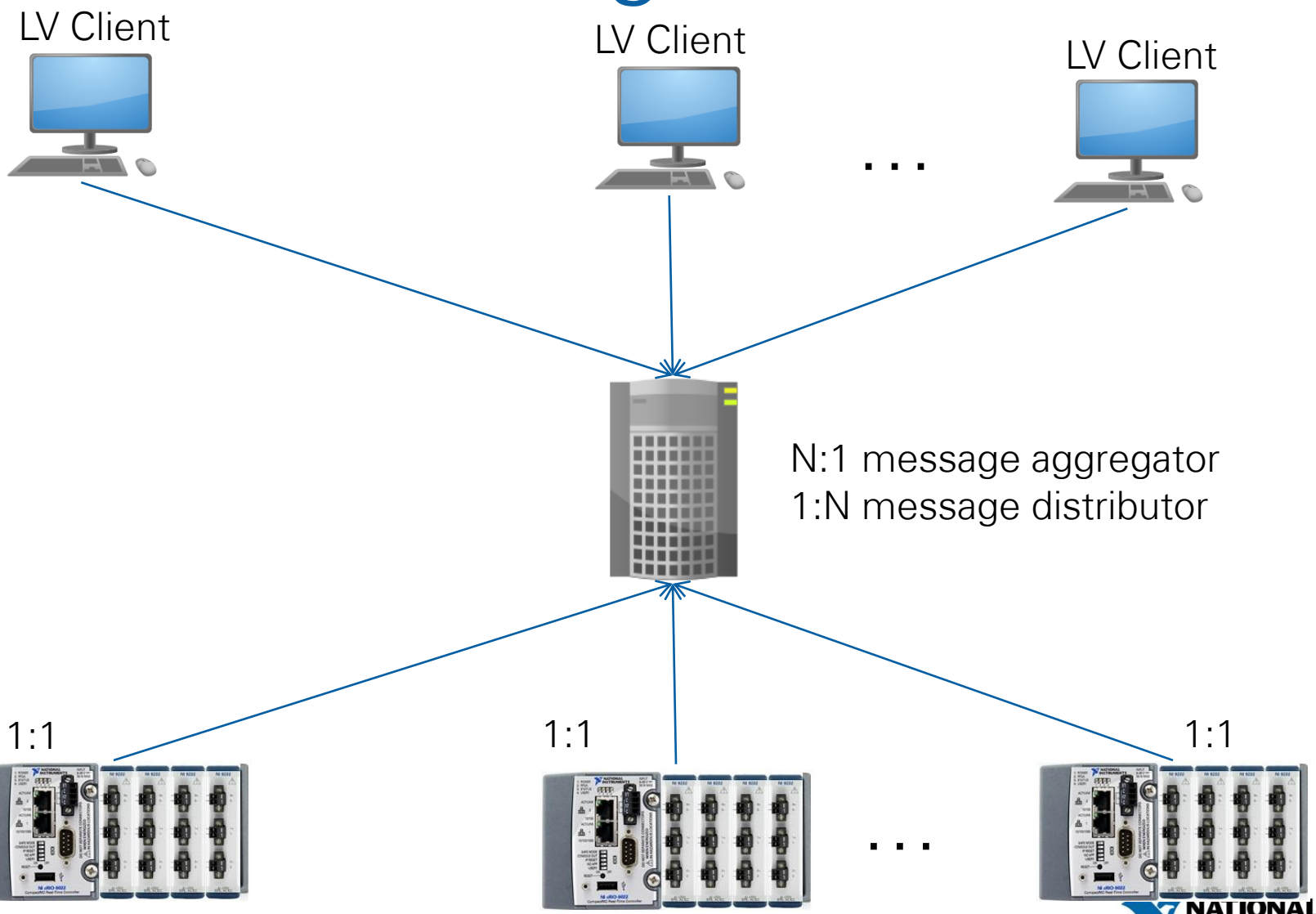
Offline Waveform Processing



Message Broker



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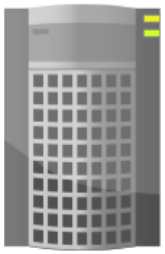

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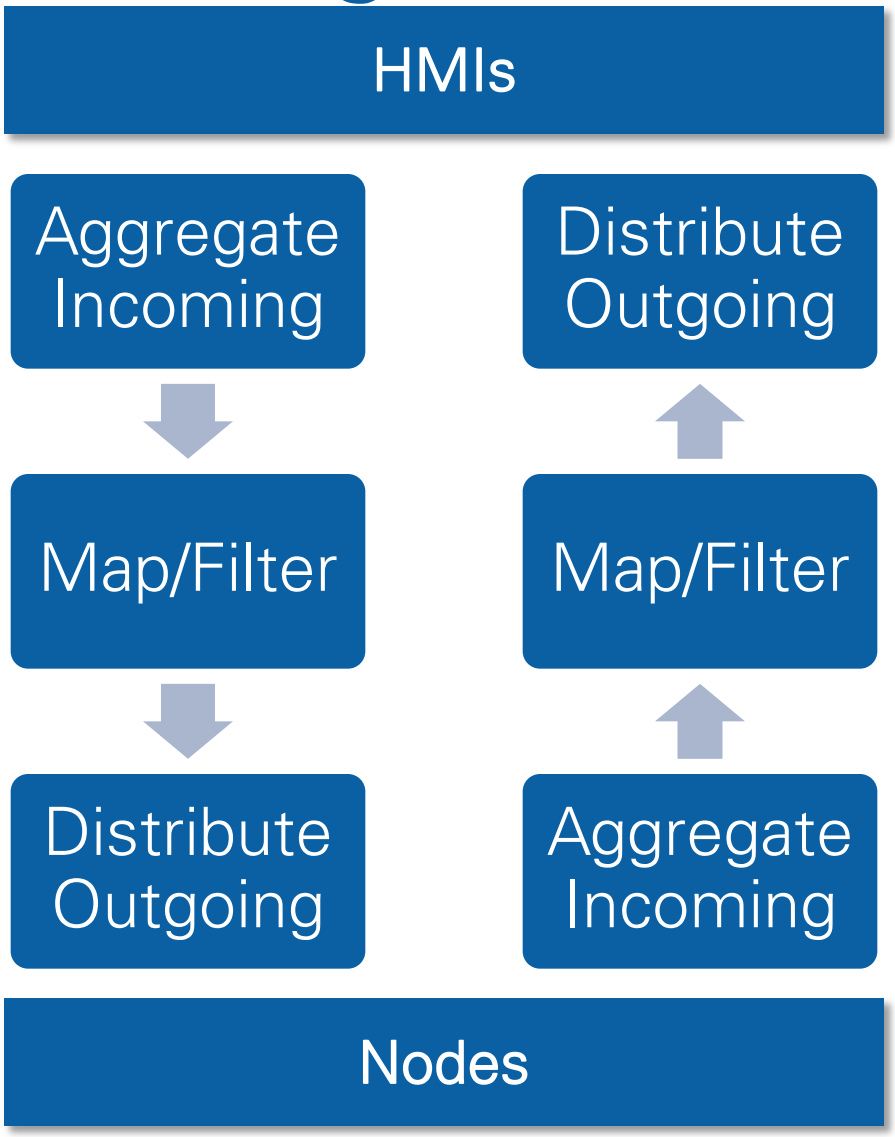

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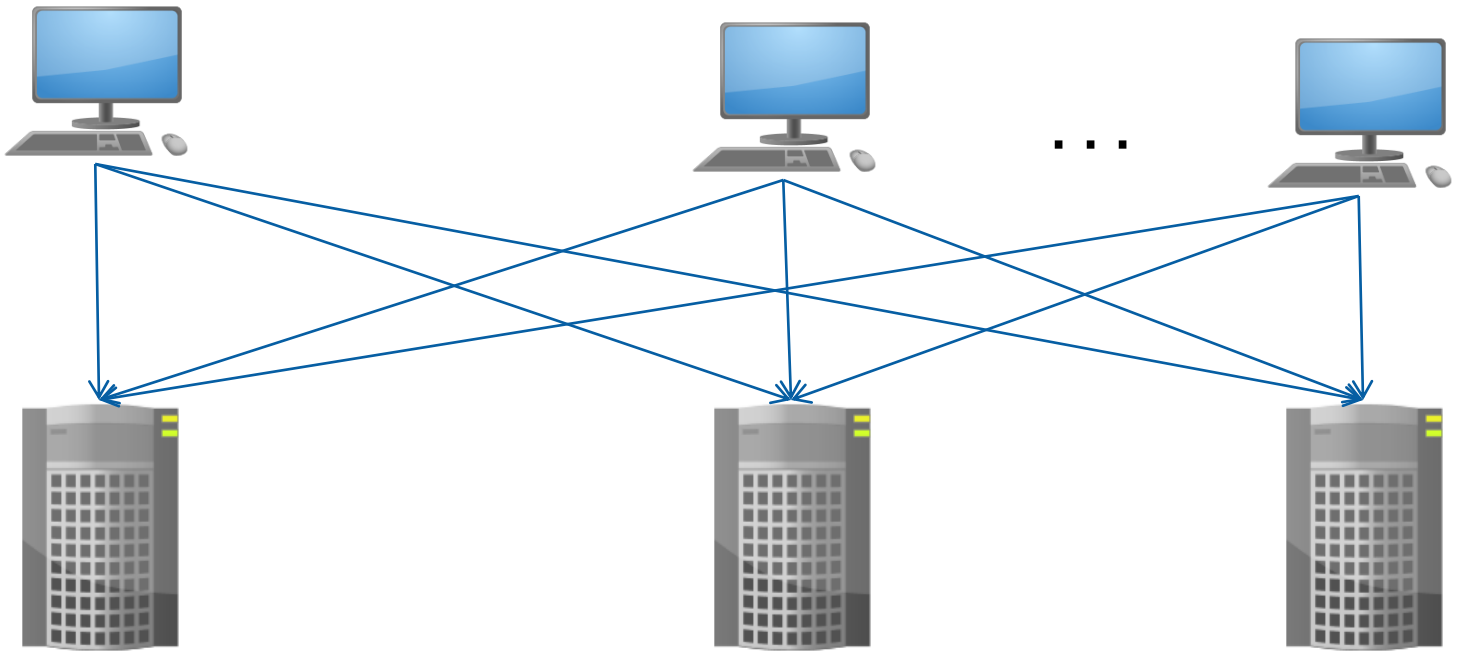
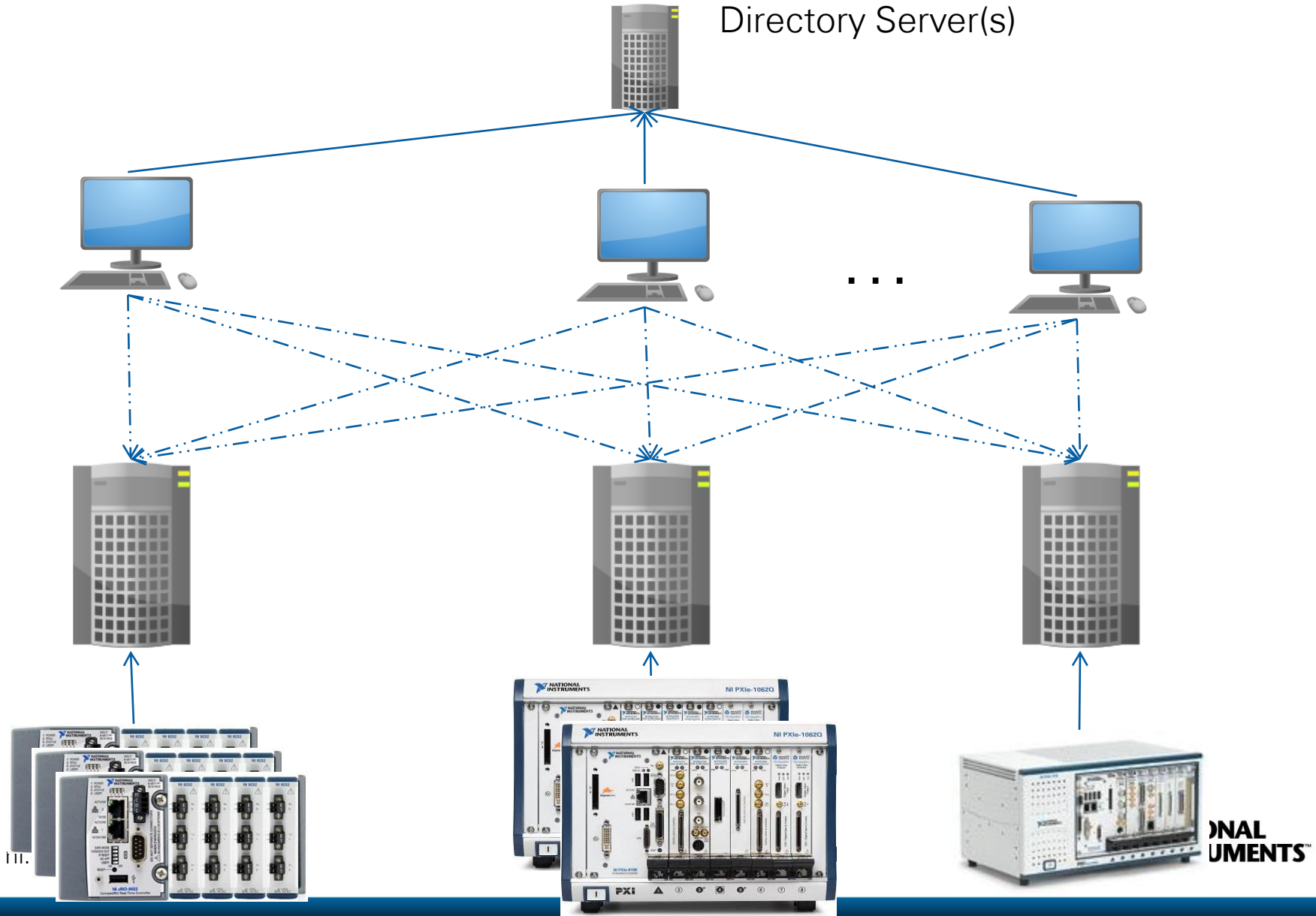
Multi-Server Architecture



Multi-Server with Lookup Service



Scalability Best Practices

- Proper communication channel selection
  - You probably need more than one!
- Minimize coupling between components (whether loops or nodes)
- Minimize configuration effort
  - Either remove the need, or automate
  - Human-readable config files are your friend
- Minimize traffic
  - Only send deltas, only send to those who need it
- Timestamp synchronization between targets