Network (Media) Access

- Token method
  - device with token controls the channel

- Polling schemes (most SCADA)
  - Solicited
  - Unsolicited
Solicited Polling

- master would send request for data to each device
- broadcast to all with ID # for specific device
- request to S3
- S3 will see request and respond before end of poll interval

Timed solicited poll
Round Robin

Master has programmed sequence

- time based
  - known delays/latencies
    (identified at system config stage)

DNP3
- integrity polls
  - going around to each device
    and each has to respond

- exception polls
  - slaves only respond if something has changed since last response
- range of variation (dead band)
  - if variation w/in dead band
don't respond

Analog inputs

Unsolicited Poll

- Slave can generate messages w/o request
- Significant change - above threshold
  or specific digital states
- Systems with limited or expensive baseband channels
Faster Channels
- multiple or new users for the channels
- Poll SCADA faster
  - Protection - wide area
    - line current differential
- PMU
- security camera
Time Division Multiplexing (TDM)

- Multiple virtual channels on one physical channel

Diagram:
- Devices (Dev1, Dev2, Dev3) connected to a multiplexer.
- Multiplexer connects to a communication channel (TX, RX).
- Demux connected to the channel with clock.
<table>
<thead>
<tr>
<th>Channel</th>
<th>Digital Speed</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSO</td>
<td>64 kbps</td>
<td>1 channel</td>
</tr>
<tr>
<td>DS1</td>
<td>24 channels each 64 kbps</td>
<td>L T1</td>
</tr>
</tbody>
</table>
Reliability

ICS - reliability a very priority up time

- Lost packets / lost data → latency
- Hardware failures
Dual Redundant Network

Master A

Master B

Substation 1

RTU 1A

RTU 1B

RTU 2A

RTU 2B

RTU 3A

RTU 3B

JED 1A

JED 2A

JED 3A

JED 1B

JED 2B

Sub 2

A - Primary

B - Backup

Failover → EMS - switched to comm with Master B
Broadcast Loop Storm

- Options to avoid

1. Rapid Spanning Tree Protocol (RSTP)
   - virtually open/sever looped path if one forms
   - find least cost path
   - dynamically traversing & monitoring network
   - better suited for data with lower speed requirement (SCADA, voice, etc)
   - can be problem in protection
Redundancy

(dynamic)

Ethernet based

RTU

3S

Reconfigure network

3S

1337

1337

1337
High Speed Seamless Redundancy (HSR) - w/o switchers
Parallel Redundancy
Measuring Failure Rates
- Qualifying failures

Single Point of Failure
- Rare, extreme event
- Single "what if"

N - 1 - N is total # of components in a system
- N - 1 is take away any one component
\[ \text{D. Dual contingency} \]

\[ N - 2 + (\text{two events not simultaneous}) \]

\[ 2^{N-1} - 1 \]
Measures of device/system performance

- How do you analyze how likely components are to fail?

- Mean time to failure (MTTF)
- Mean time between failures (MTBF)
- Mean time to repair (MTTR)

MTBF = MTTF + MTTR

Units of time:
- Hours
- Days
- Years
Unavailability

$q = \frac{MTTR}{MTBF} = \frac{MTTR}{MTTF + MTTR}$

MTTR can be short for JCS equipment

If you stock spares

MTTF >> MTTR for a lot of JCS equipment

MTBF ≈ MTTF
p is generally small

P = \text{availability, } \hat{p} = 1 - \hat{q} = 0.9999 \uparrow

failures

fault tree analysis