Wireless Architecture for Secure and Reliable Communications

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WNSIA – Robust Wireless Architecture For Industrial Sensing

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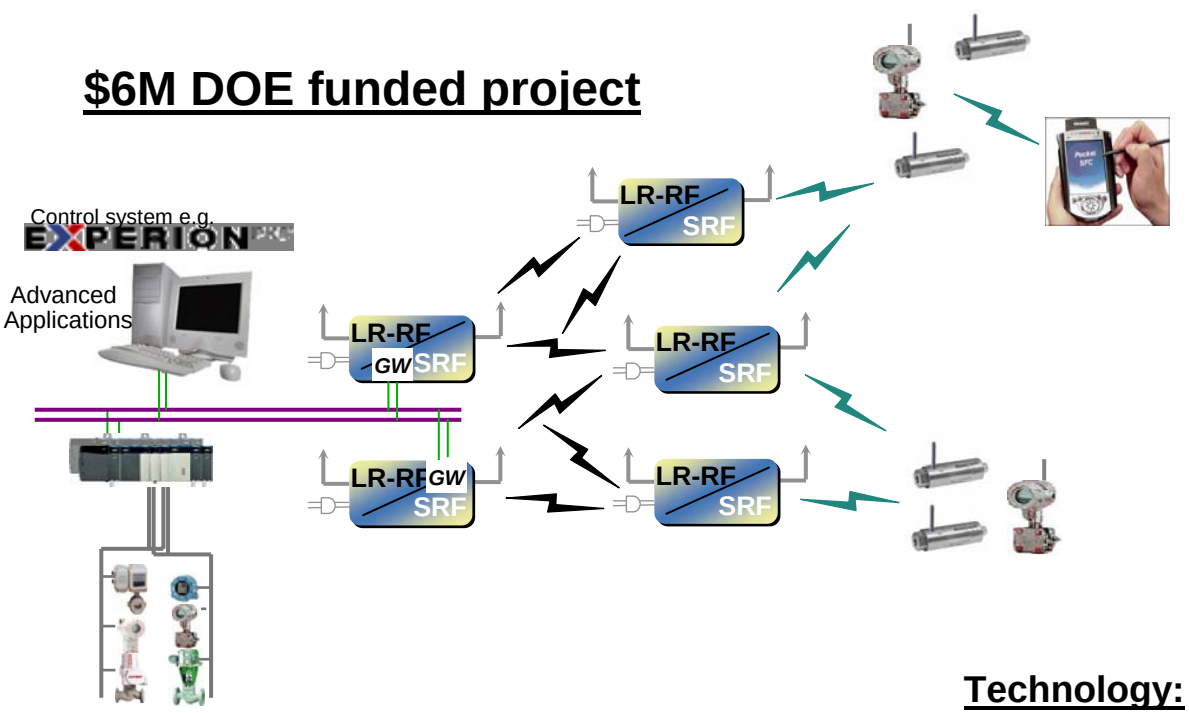
$6M DOE funded project



Voice of Customer-

- *Installation (wiring cost) savings*

CTQs:

- *Reliable wireless - "as good as a wire",*
- *Secure communications*
- *> 3 year product life*
- *Low-cost devices*

Unique wireless architecture provides robust data delivery while minimizing power in battery powered sensors - scalable to large systems...

WNSIA Differentiators

- **Robust & secure communications**
- **Lowest cost wireless**
- **High scalability**
- **Simple deployment - w/o RF surveys**

Technology:

- **Network architecture**
  - **Powered, store-and-forward infrastructure nodes (INodes)**
  - **Low-power sensor RF links**
- **Redundant (non-overlapping) latency-controlled routing**
- **Sensor RF optimized for robustness and battery life**
  - **Unique power optimized spread spectrum**
- **Many sensors reporting to each INode**

WNSIA Wireless System - Key Requirements

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1. Reliable communications
   - Robust to single point failures
   - Resistant to interference / jamming

2. End to end latency control
   50% of reporting period.

3. Capacity and Scalability
   1000 Leaf Nodes, 100 INodes

4. Success Rate
   95% of latency-controlled packets delivered.

5. Localized Faults

6. Global Solution / standard

7. Co-existence with 802.11b/g

8. Multiple periodic reporting rates
   250ms to 1 hour or more.

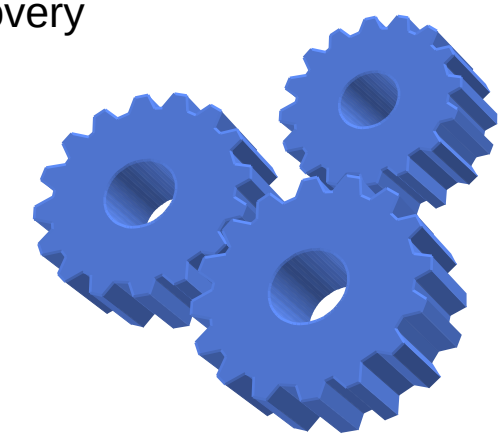
9. Data QoS Classes
   1. Latency Control 2. High Throughput 3. Immediate 4. Low Importance

10. Security
    Privacy, Integrity, Authentication, Key management

11. Diagnostics /Alarm reporting

12. Power cycle recovery

13. Battery Life
    > 3 years



Constraints in Wireless Networks

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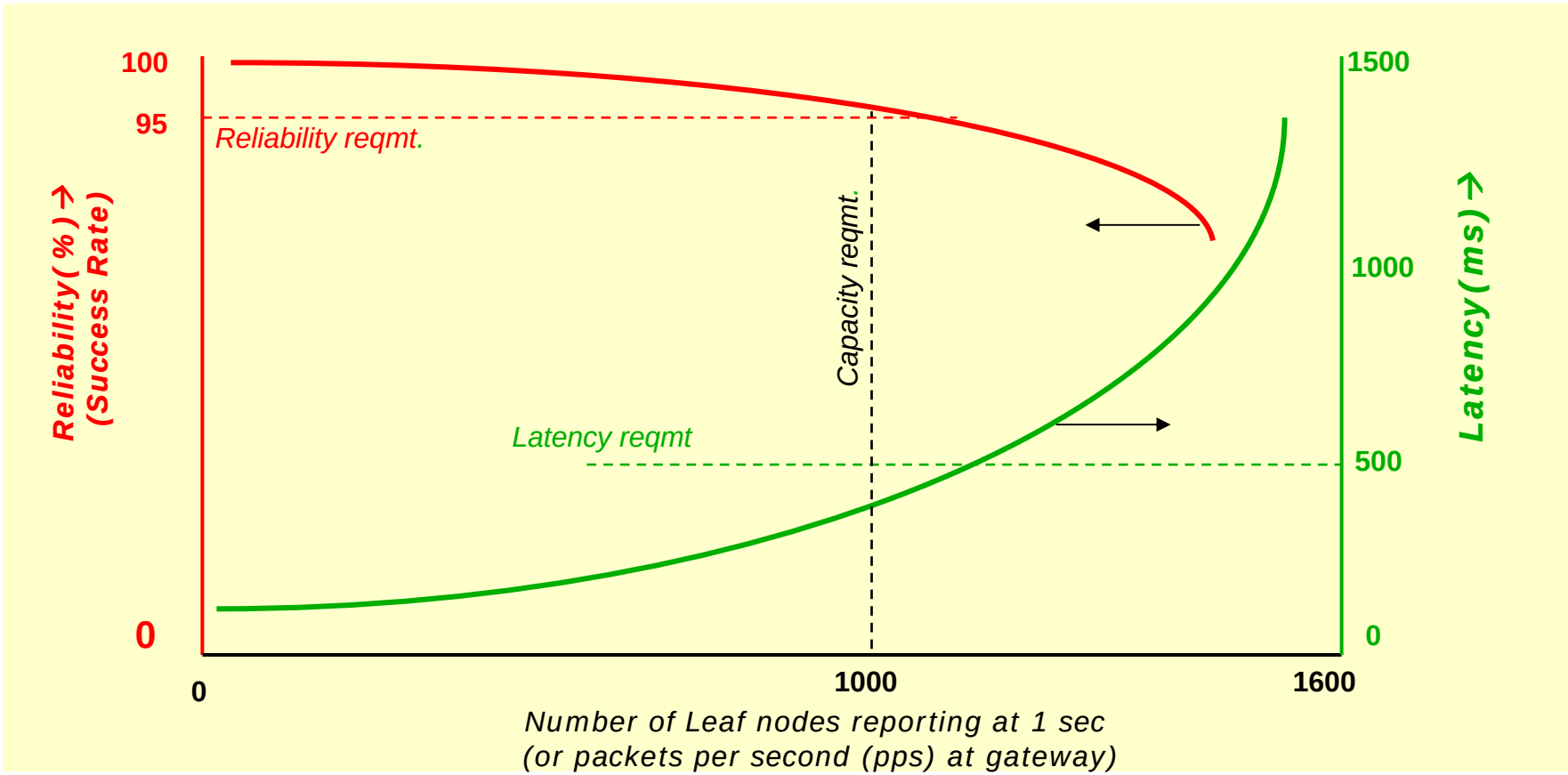
➢ ***Challenge: Achieving high capacity while maintaining required success rate and latency limits***



WNSIA System Architecture

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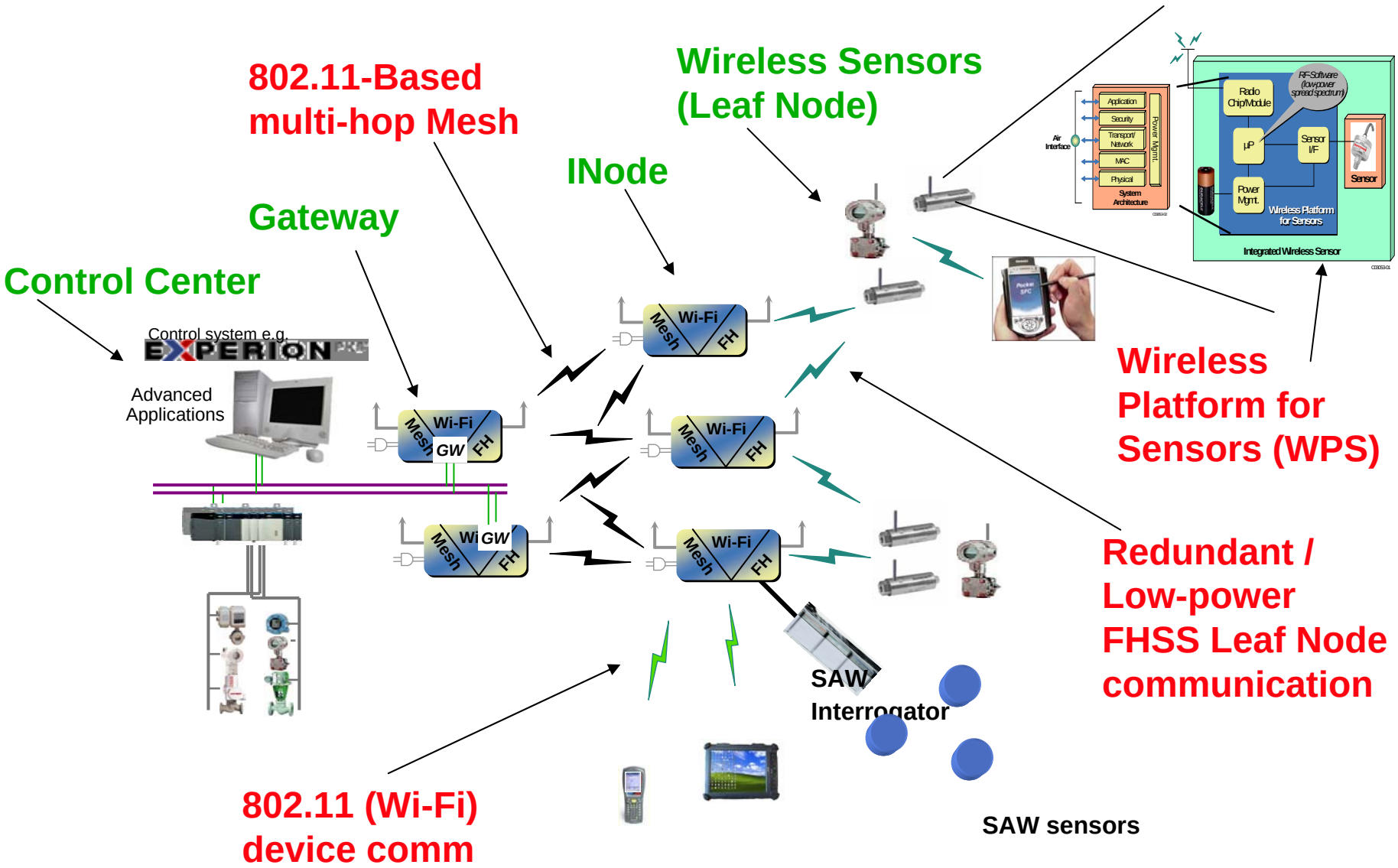

Time Synchronization

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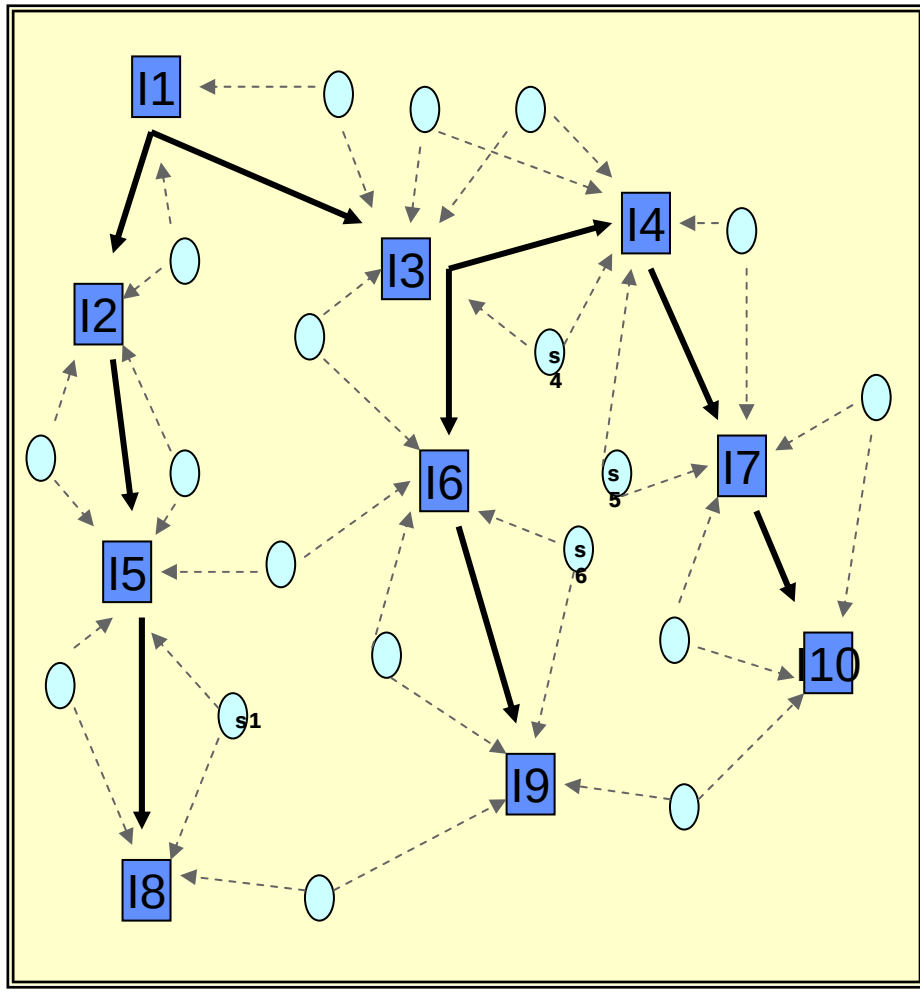
- The Network forms a spanning tree of nodes (called a Cluster) for purpose of time synchronization.
- Every Node (except the cluster master) tracks a periodic broadcast of its master's clock and corrects its clock accordingly.
- A network wide time synchronization is achieved in this manner.
- Time synchronization is essential for FH communication and redundant connectivity.
- Synchronization of upto 30 us between levels demonstrated with 32KHz , 12ppm crystals.



Robust Time Synchronization protocol ensures reliable frequency hop and redundant communications

Design for Robust Reliable Communications

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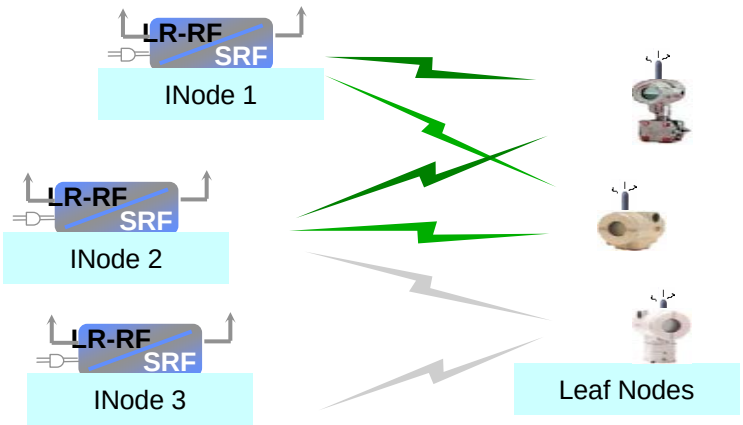
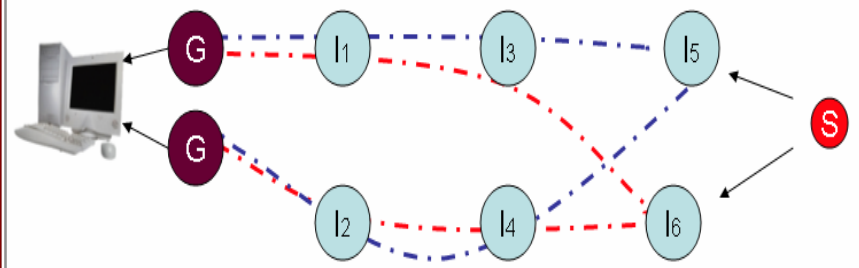
Redundant Connectivity



- Each leaf node Tx is **received simultaneously** at two INodes.
- Leaf nodes "sleep" between transmissions. Clock synchronization and wake up orchestrated by INodes.

- *Redundant Connectivity with single Leaf Node TX*
- *Low-power FH-SS*
- *Input &/or Output Nodes (Sensors & actuators)*
- *Ease of Installation*
- *Event Channel*
- *Individual RF Reporting Rates per Leaf Node*

Redundant Routing



- Two **non-overlapping redundant, latency controlled** routes calculated from each INode to the gateway pair
- Optimal routes calculated by taking into account a combination of **number of hops, total link quality of the route and INode bandwidth utilization**

- *Robust to INode device and link failures – Leaf node message delivery is not affected by any single point failure.*
- *End to end latency control between the Leaf nodes and gateway pair*

Design for Low Power Consumption

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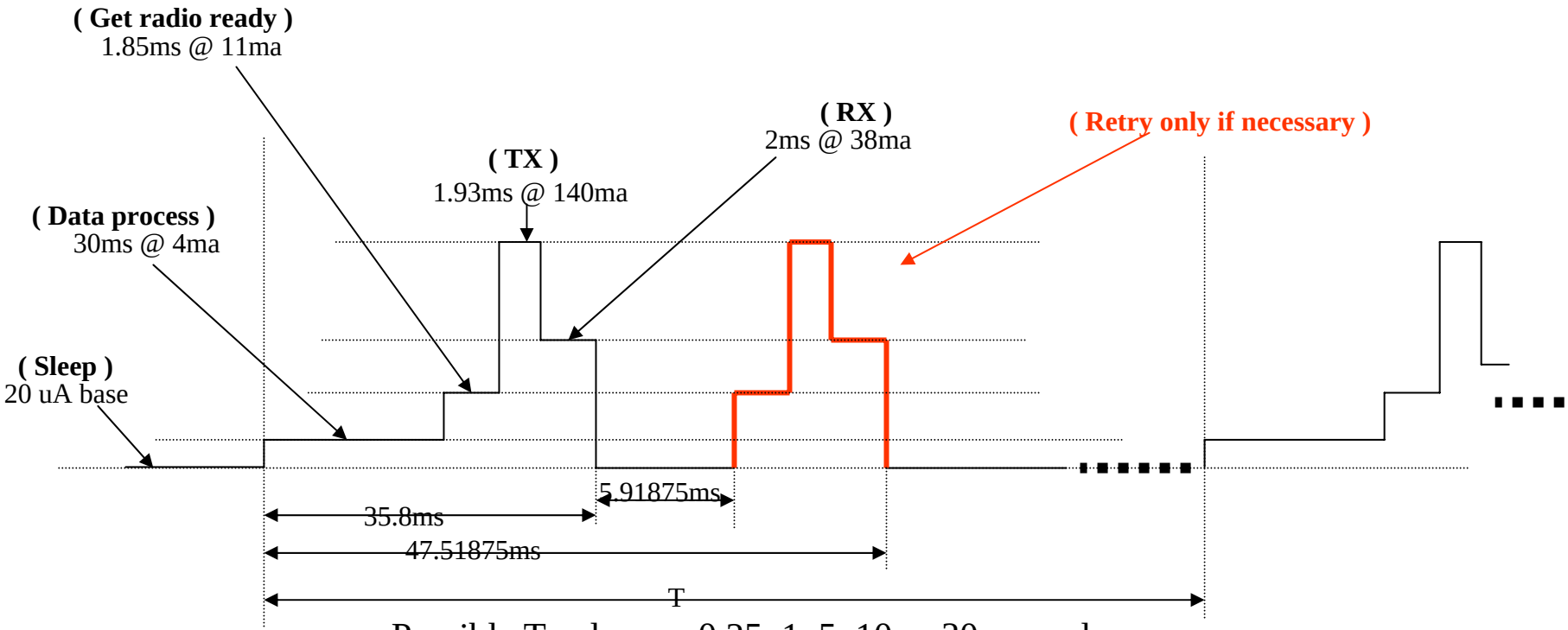

Possible T values = 0.25, 1, 5, 10 or 30 seconds

Transmit Period	Battery Life (years)
30	*shelf life*
10	*shelf life*
5	*9.1 years*
1	*2.1 years*

Application to Fly-by-Wireless

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- **Requirements for a wireless system are similar to the that of a industrial control system**
  - **Reliability , Latency Control, Security and Cost**
- **Consider frequency hopping or frequency agile systems**
- **Design heterogeneous Networks**
  - **Powered high-bandwidth router nodes with a high performance microprocessors**
    - Form a mesh network and responsible for routing
  - **Less complex sensor nodes**
    - Battery powered (or SAW based) Sensor nodes
    - Transmit and sleep (no routing)
- **Consider different QoS Classes**
  - **Redundant connectivity and multipath routing for latency controlled data.**
  - **End to End Acknowledgements for highly reliable data.**
  - **Aggregate and cache data if necessary**

Design Overview

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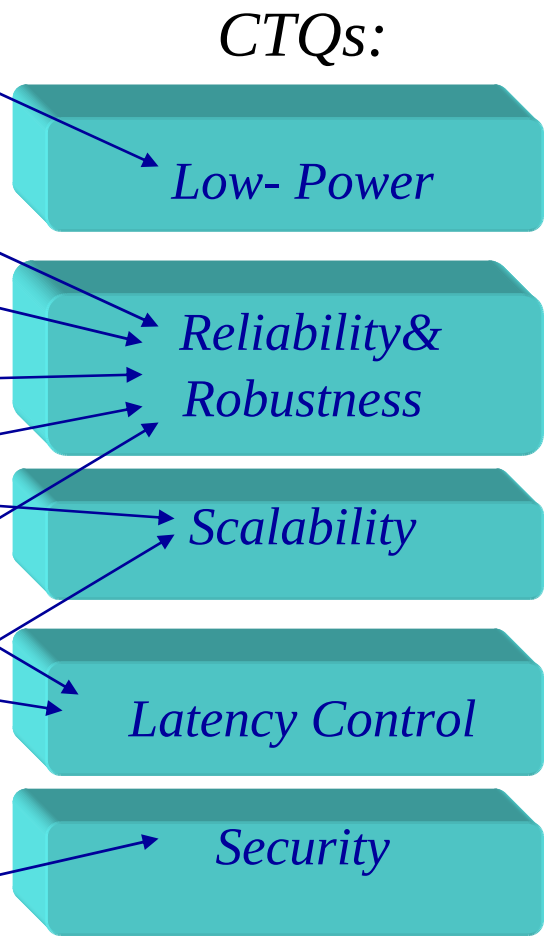
Features:

1. *Transmit and sleep, non-routing Leaf Nodes*
2. *Frequency hopping communication*
3. *Redundant links between INodes and Leaf Nodes*
4. *Redundant gateways*
5. *Mesh network of INodes with multipath routing*
6. *Non-overlapping redundant routing*
7. *Multiple gateways to existing control system*
8. *Security with simple key management*



System Architecture

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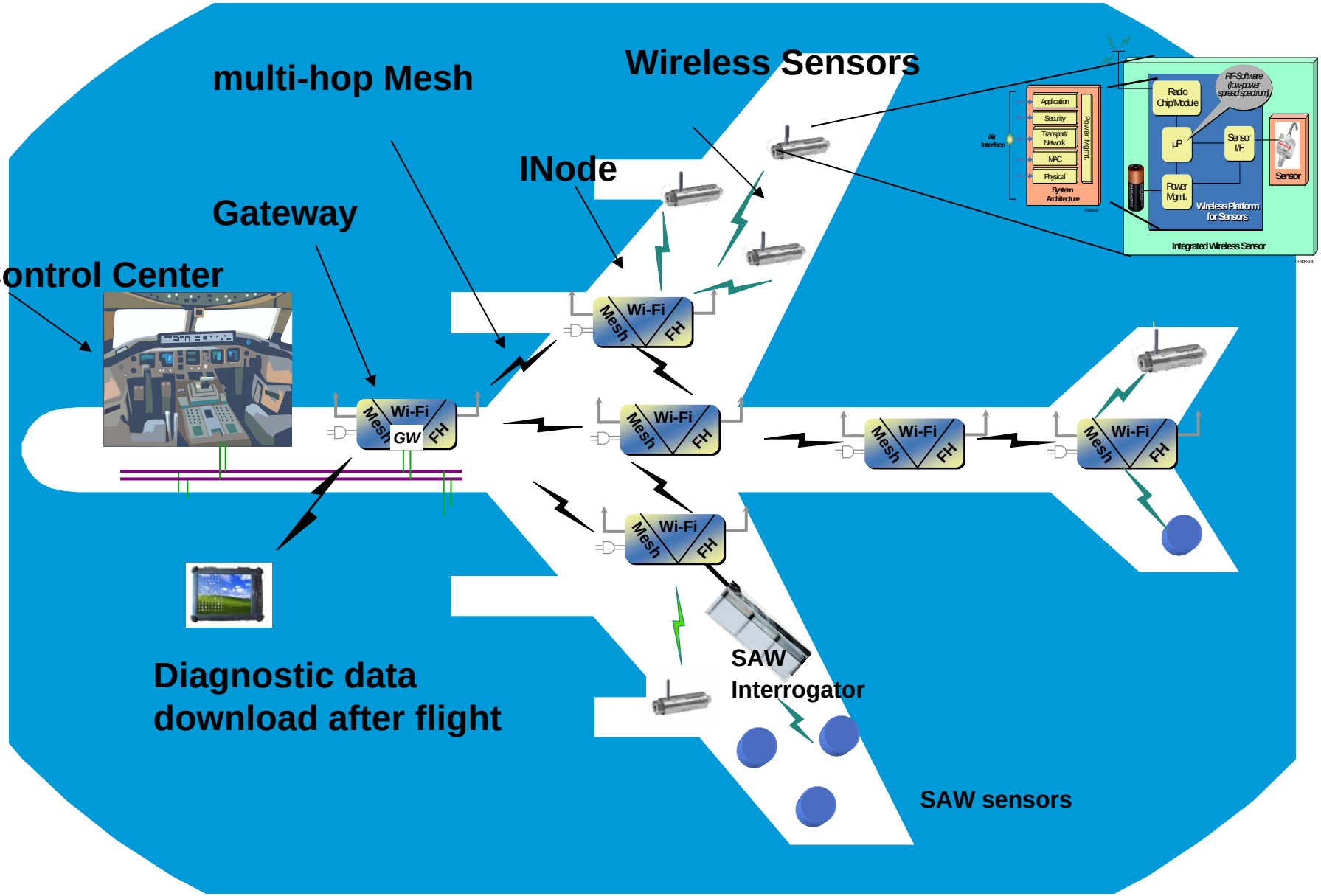

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