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# WIRELESS SENSOR NETWORKS

The Future is Wireless

**By S H TAN**



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- **Definition of WSN**
- **How does it work**
- **Application Example**

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“..the number of transistors on a  
chip doubles every 24 months..”

Gordon Moore

## Definition Wireless Sensor Network

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A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure sound, motion or pollutants

Wikipedia

## Definition Cont'...

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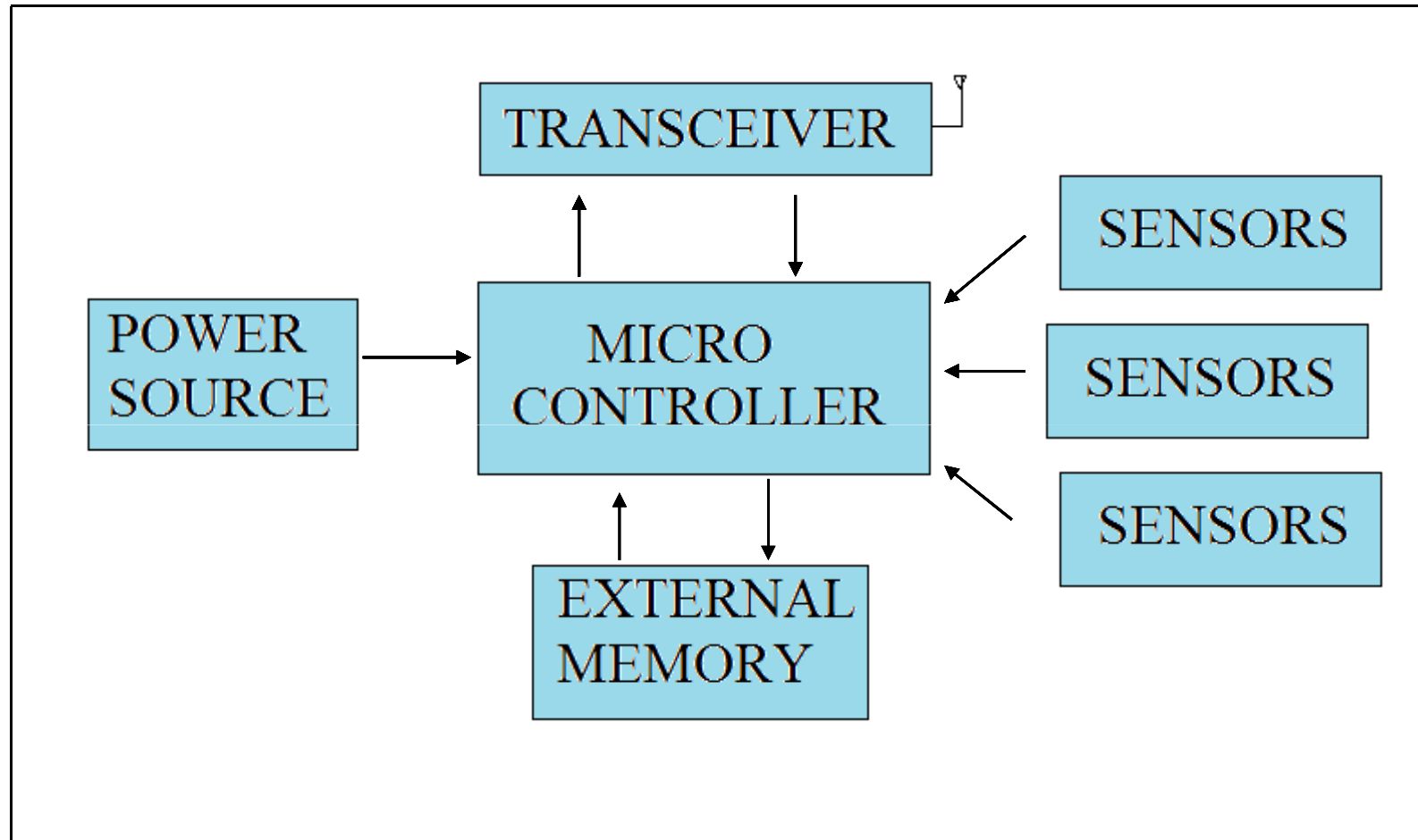
Wireless sensor networks combine processing, sensing and communications into tiny embedded devices.

*... emphasize low-cost components operating on shoestring power budgets for years at a time in potentially hostile environments without hope of human intervention.*

Jason Hill, Mike Horton, Ralph Kling,  
and Lakshman Krishnamurthy

# HOW IT WORK

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## Focus on Low Power

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POWER : Limited Resource



**THERE IS NEVER ENOUGH POWER**

# SOLUTION

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## USE BIGGER BATTERIES

- Size Constrain

## PLUG INTO MAINS

- Usually not feasible

## USE RENEWABLE RESOURCE

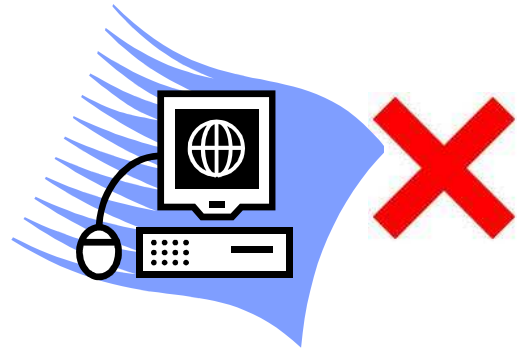
# CONSERVEVATION

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# CONSERVATION

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MICROCONTROLLER NOT MICROPROCESSOR

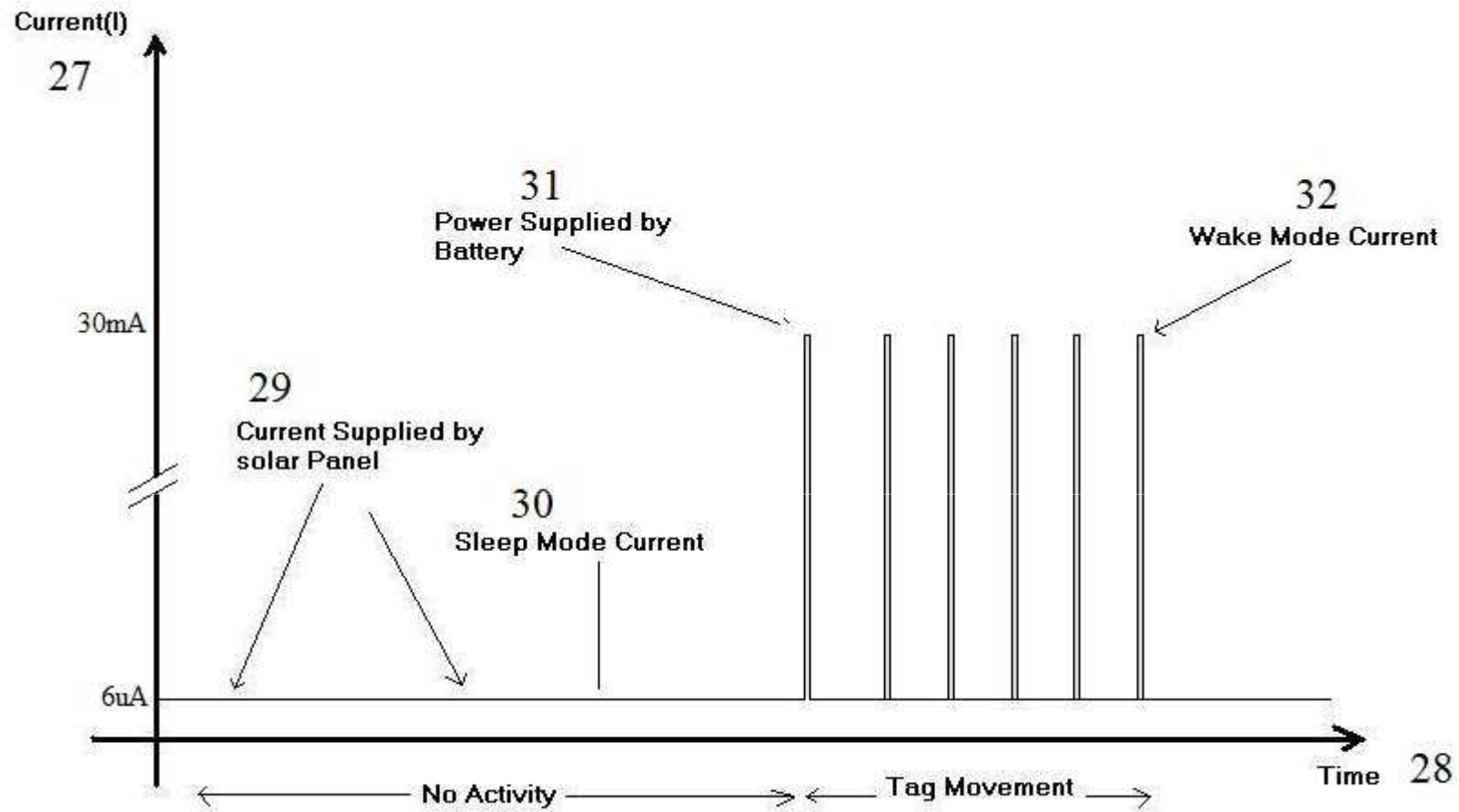


BETTER SYSTEM ALGORITHM TO CONSERVE POWER

LOW POWER RADIO -Typically 20-50m range



# Better Algorithm



## SLEEP WAKE DUTY CYCLE

## Short Distance Radio

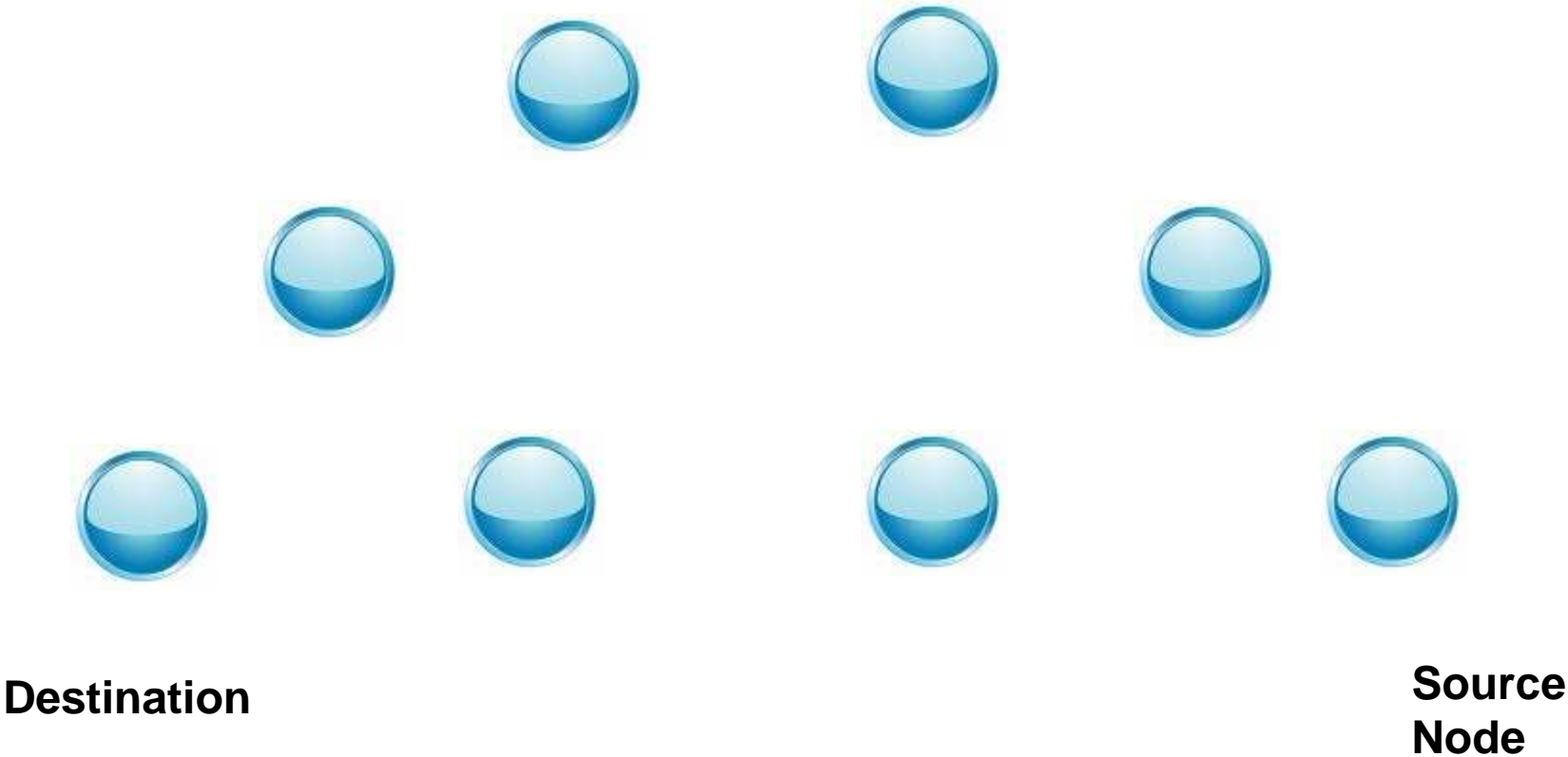
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- Need corporations from neighboring units to relay data



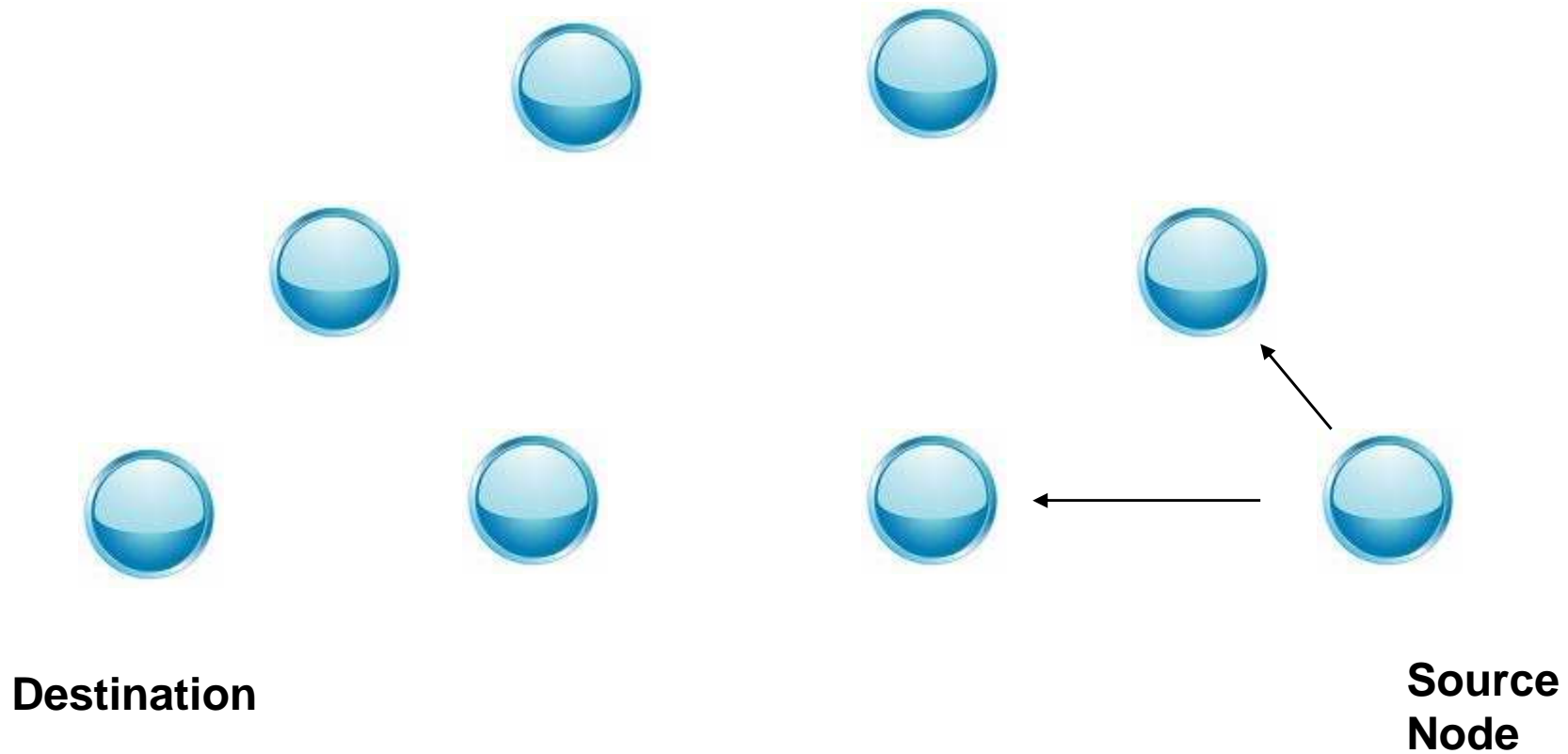
# How It work - Mesh Network

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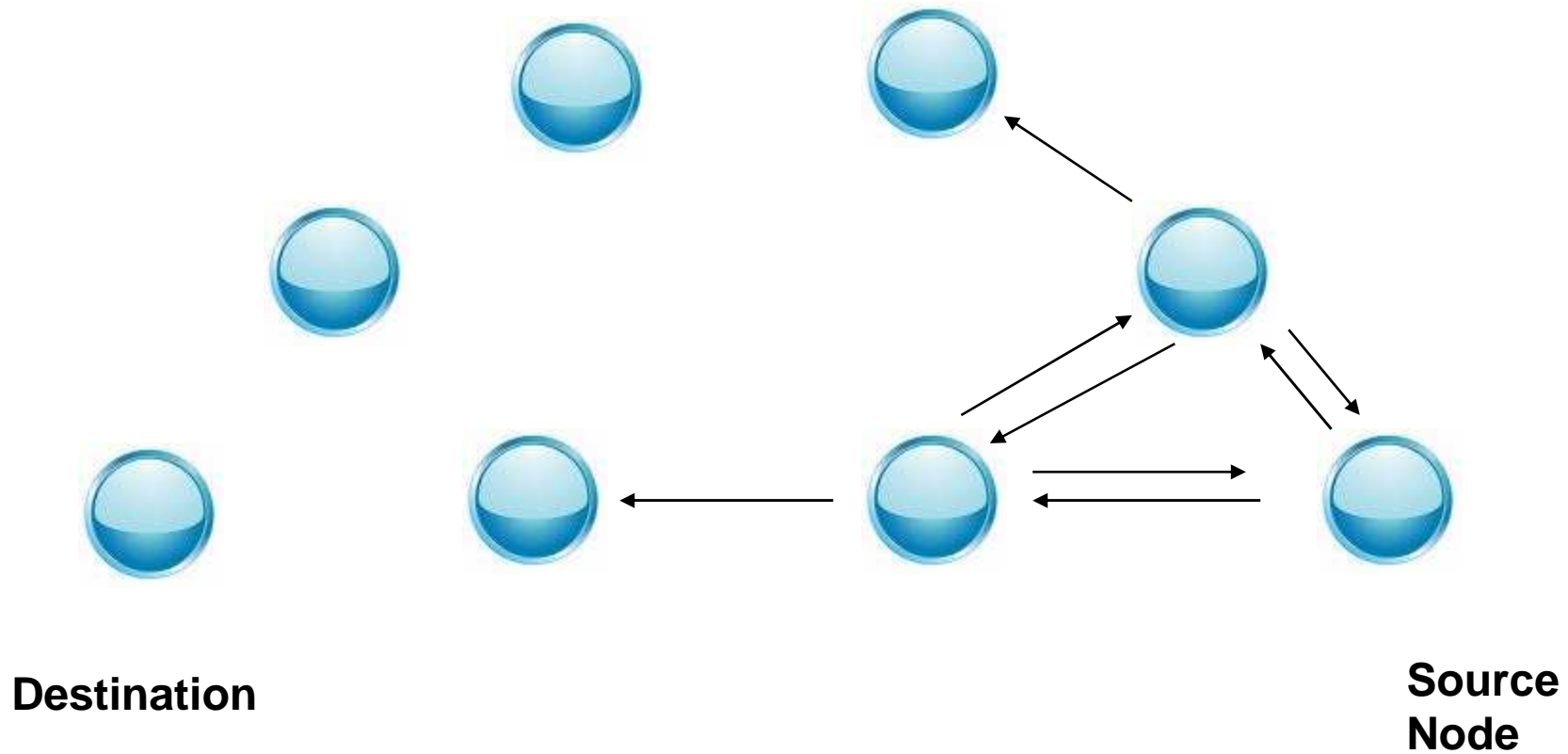
# How It work - Mesh Network

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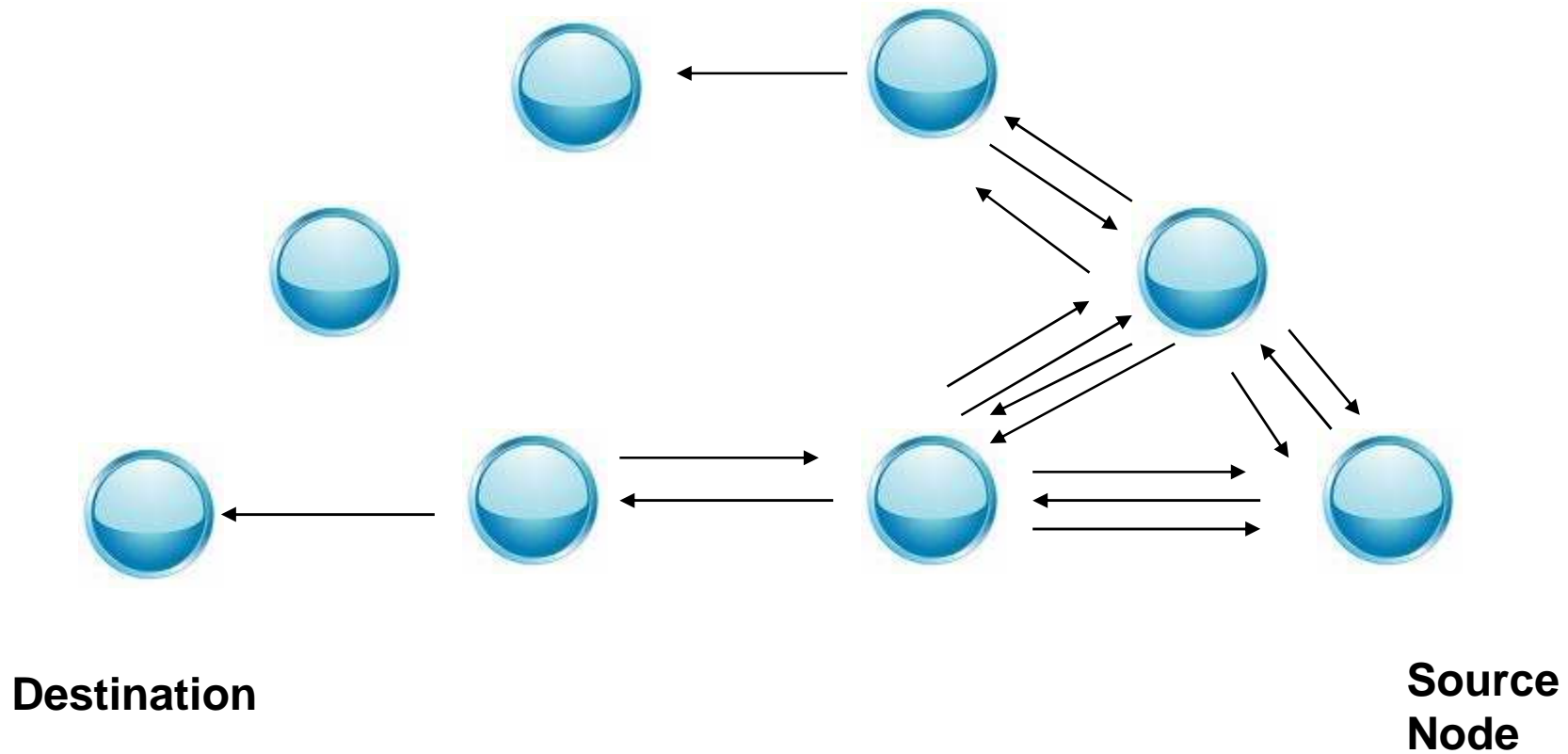
# How It work - Mesh Network

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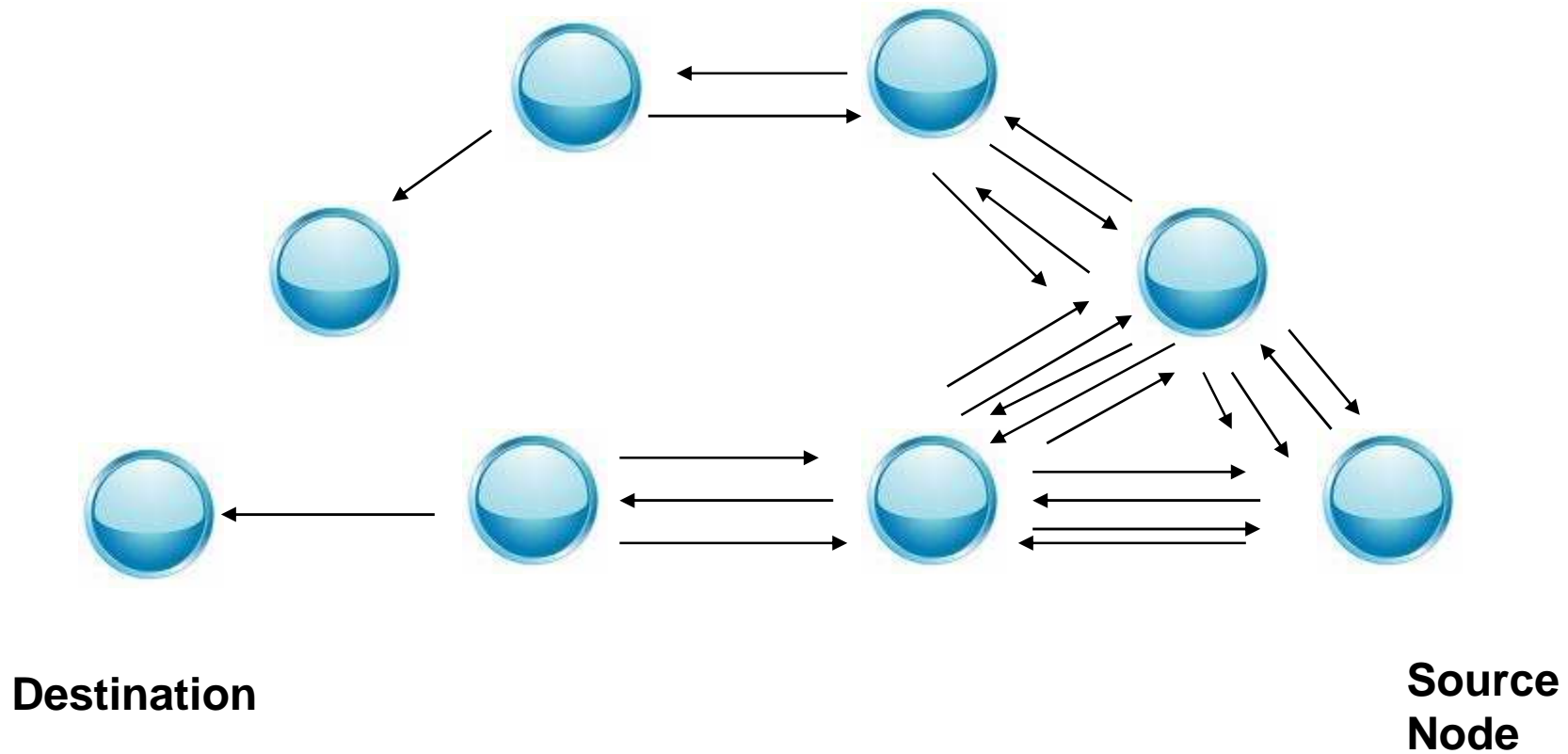
# How It work - Mesh Network

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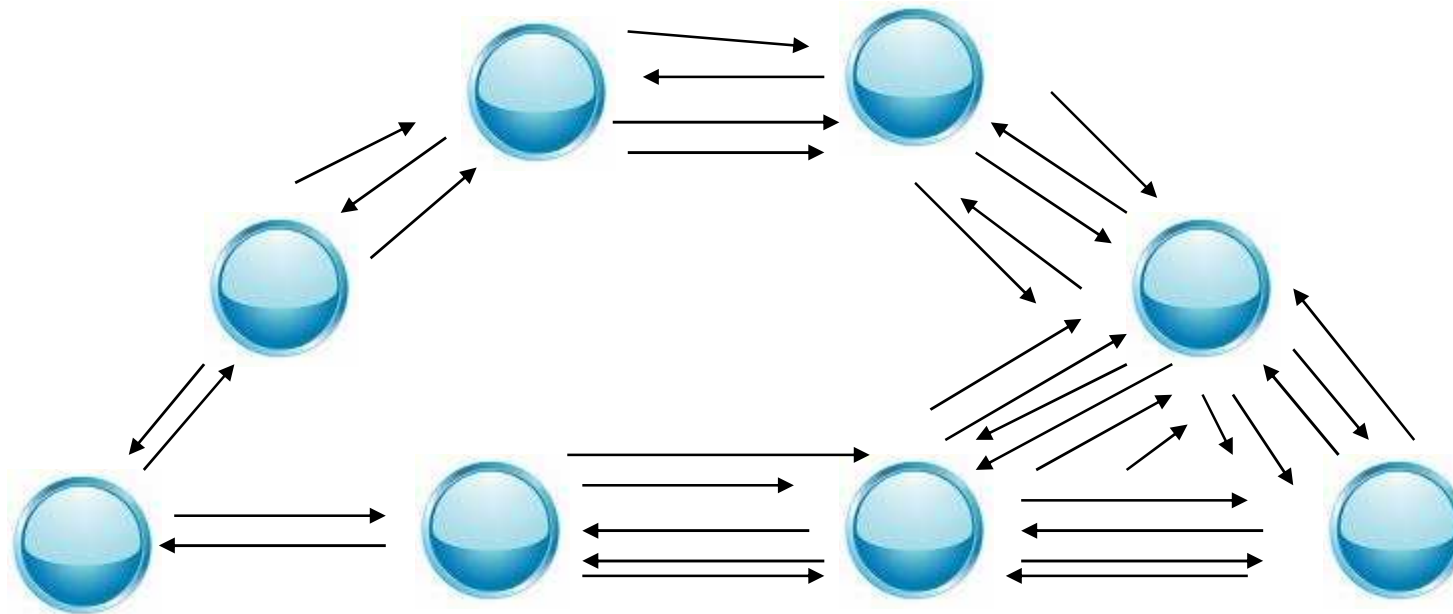
# How It work - Mesh Network

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# How It work - Mesh Network

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Destination

**GRID LOCK**

Source  
Node

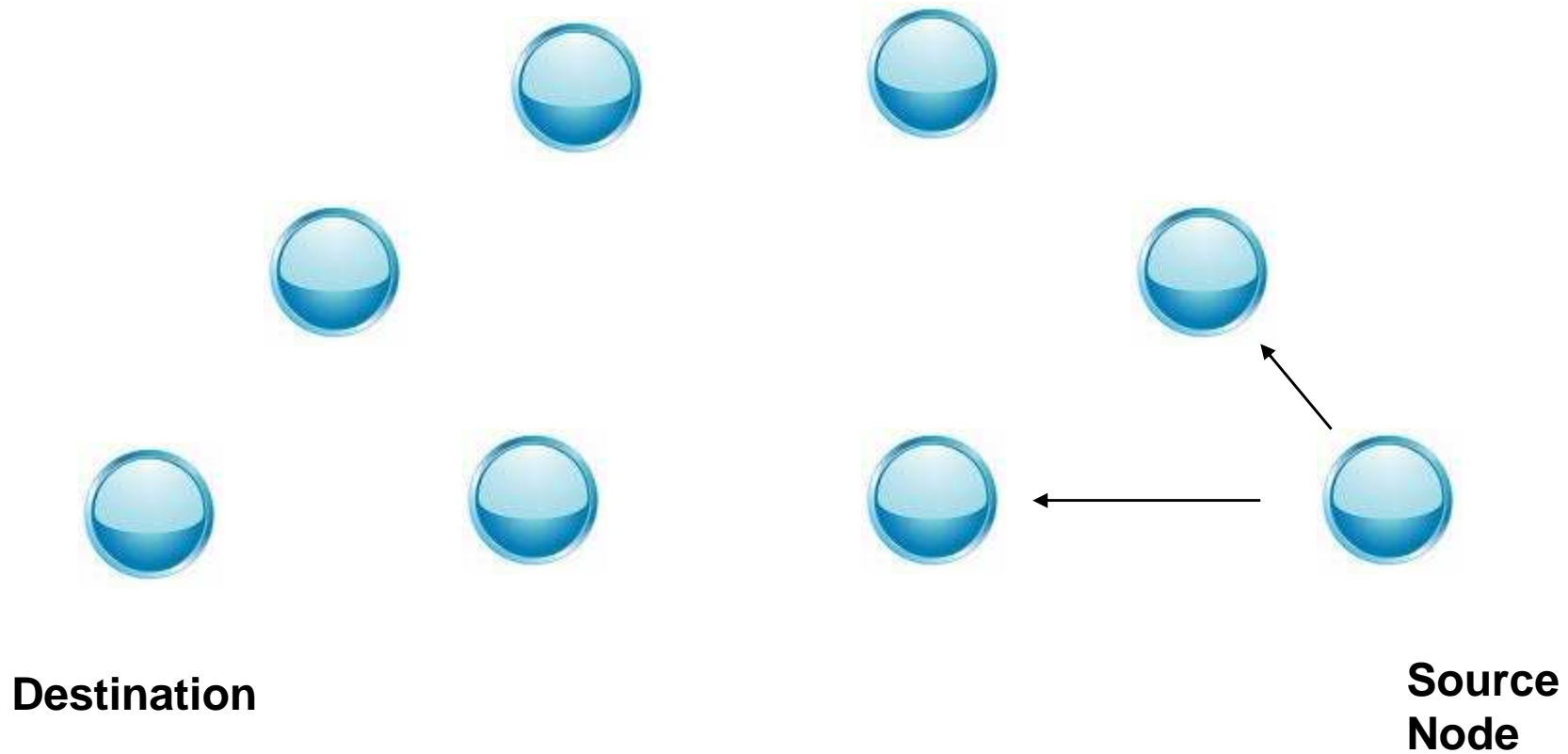
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# MUST BE A BETTER WAY

1. Prevent Back Tracking
2. Signal Must Be Terminated after a number of hops
3. Do not resent the same packet

# How It work - Mesh Network

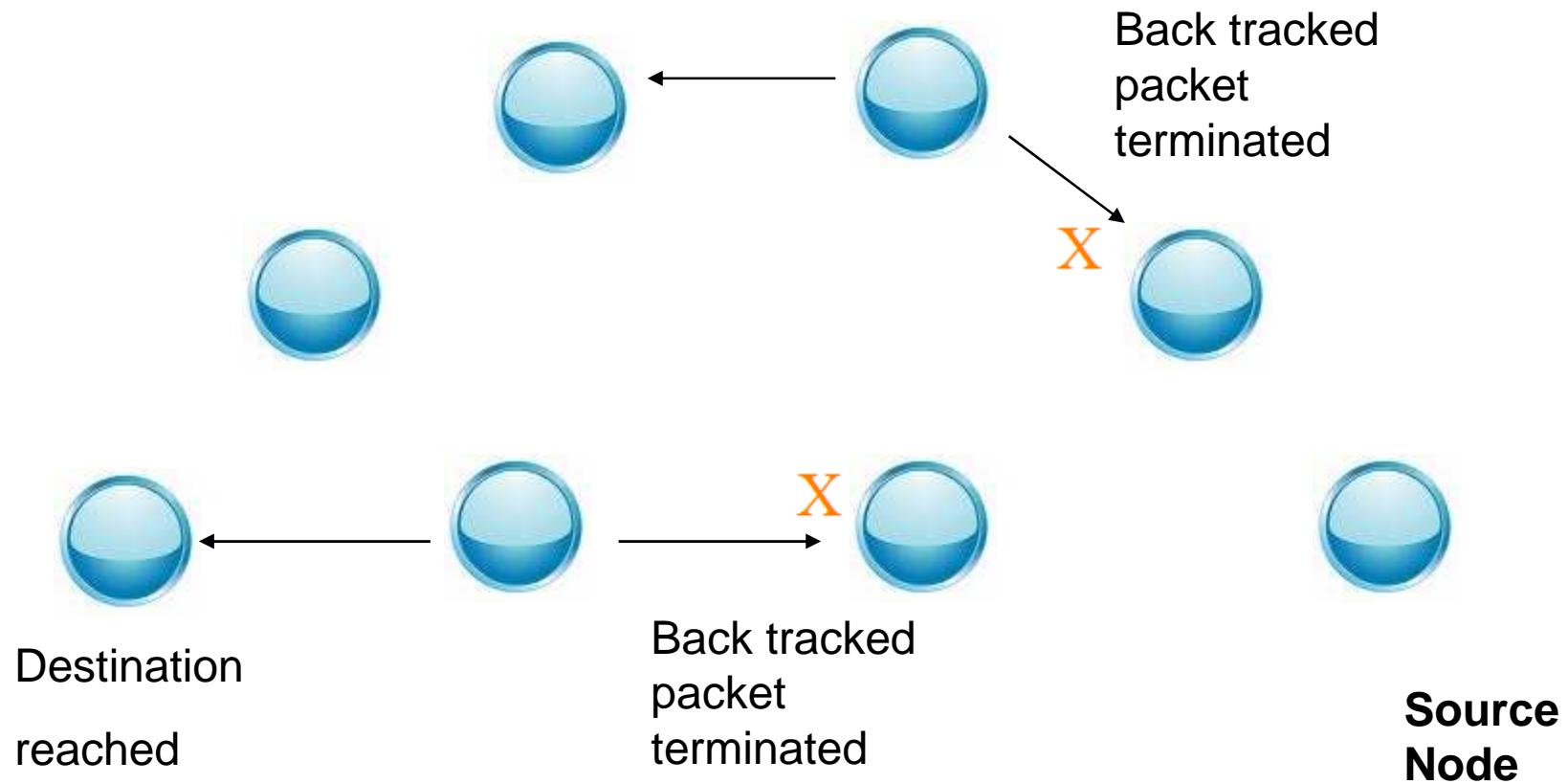
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# How It work - Mesh Network

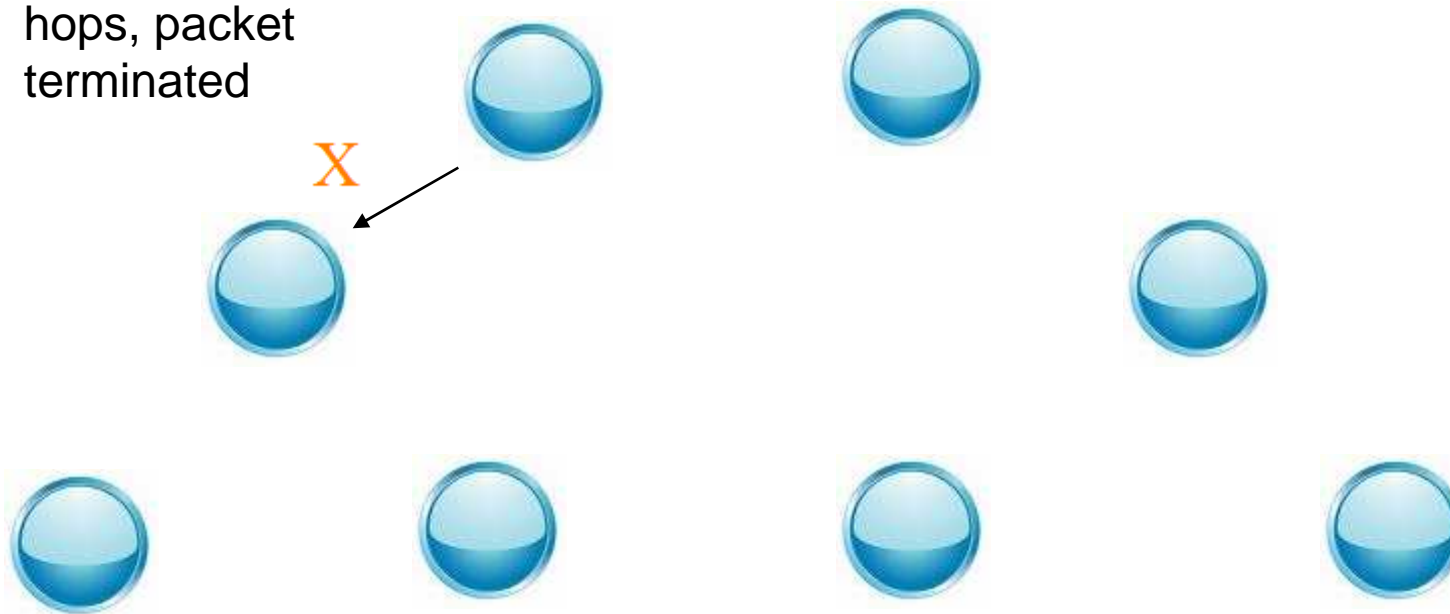
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# How It work - Mesh Network

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Too many hops, packet terminated



Destination

Source  
Node

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# Finally - New Standard Emerges



# Emerging Standards

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IEEE 802.15.4 - 2006

-Physical Layer

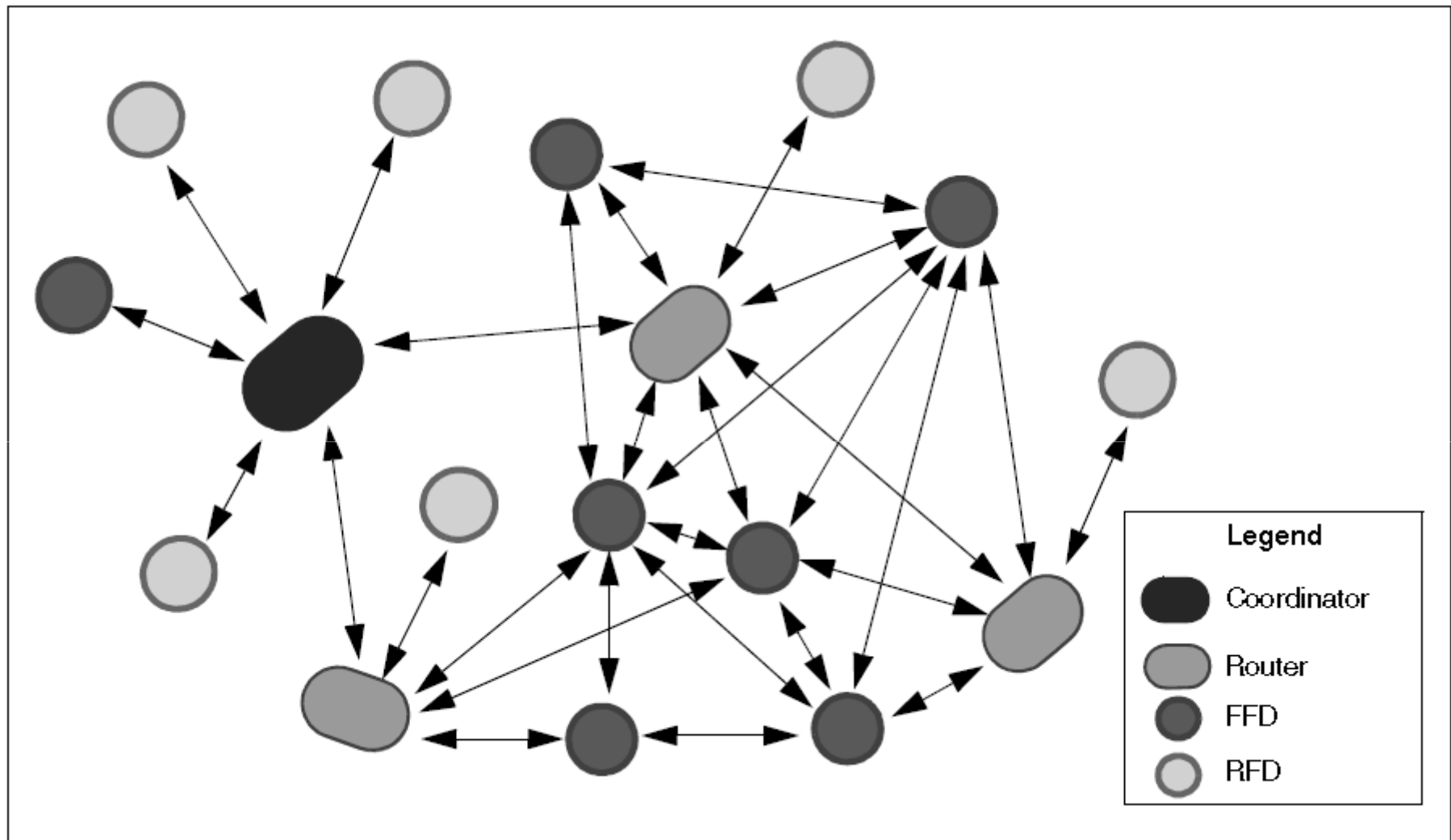
-MAC Layer

- ZigBee
- 6loWPAN
- WirelessHART
- MiWi

**ALLOW SYSTEMS TO INTEROPERATE**


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# EXAMPLE: ZigBee



# ZigBee

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 Coordinator

**Forms the network, Allocate Network Address,  
holds binding table**

 Router

**Extend the physical range of the network. Allow  
more node to join**

 FFD

**FULL FUNCTION DEVICE**

 RFD

**REDUCE FUNCTION DEVICE**

## Design of a security system - Case Study

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- Complexity increases
- Big code footprint
- No longer simple
- Lag time to join the network. Similar to PC logging on to AP
- Have to work with 4 different components

**Houston, we got a problem**

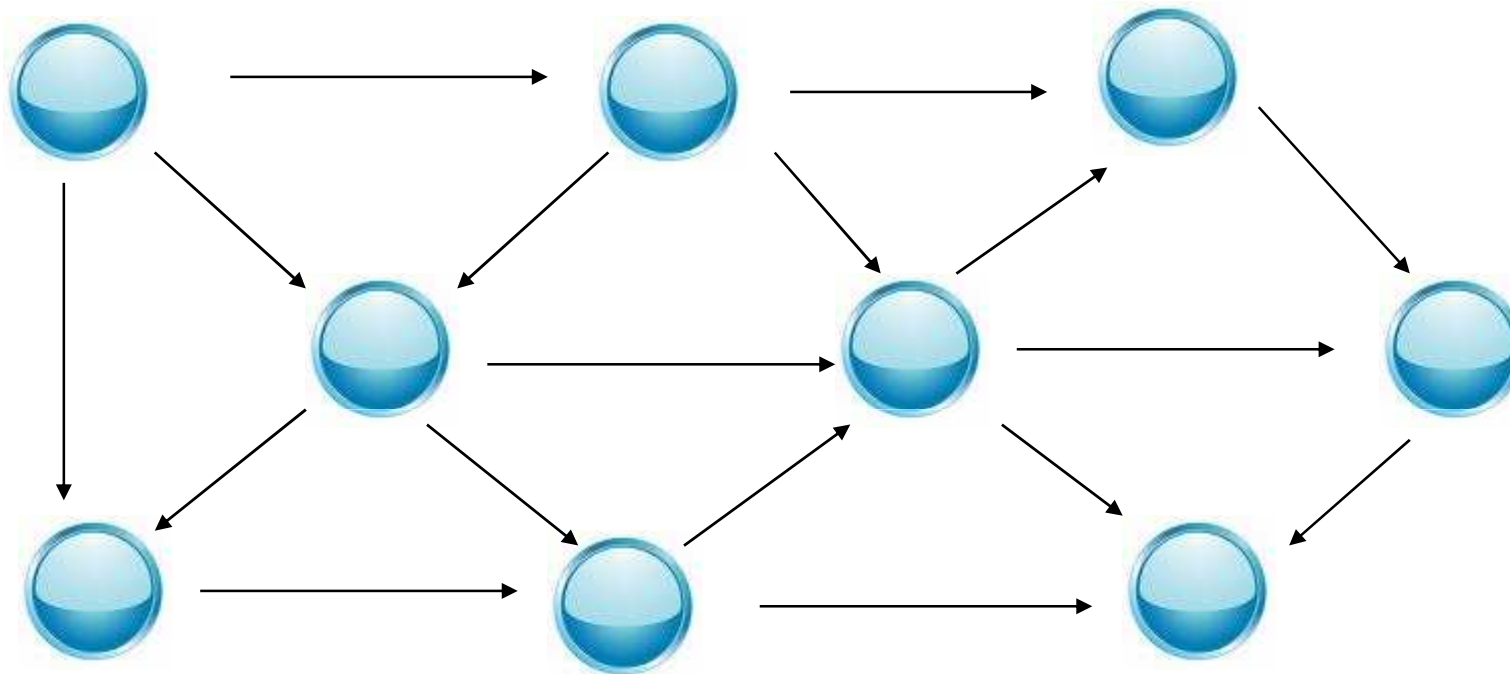
# Requirement

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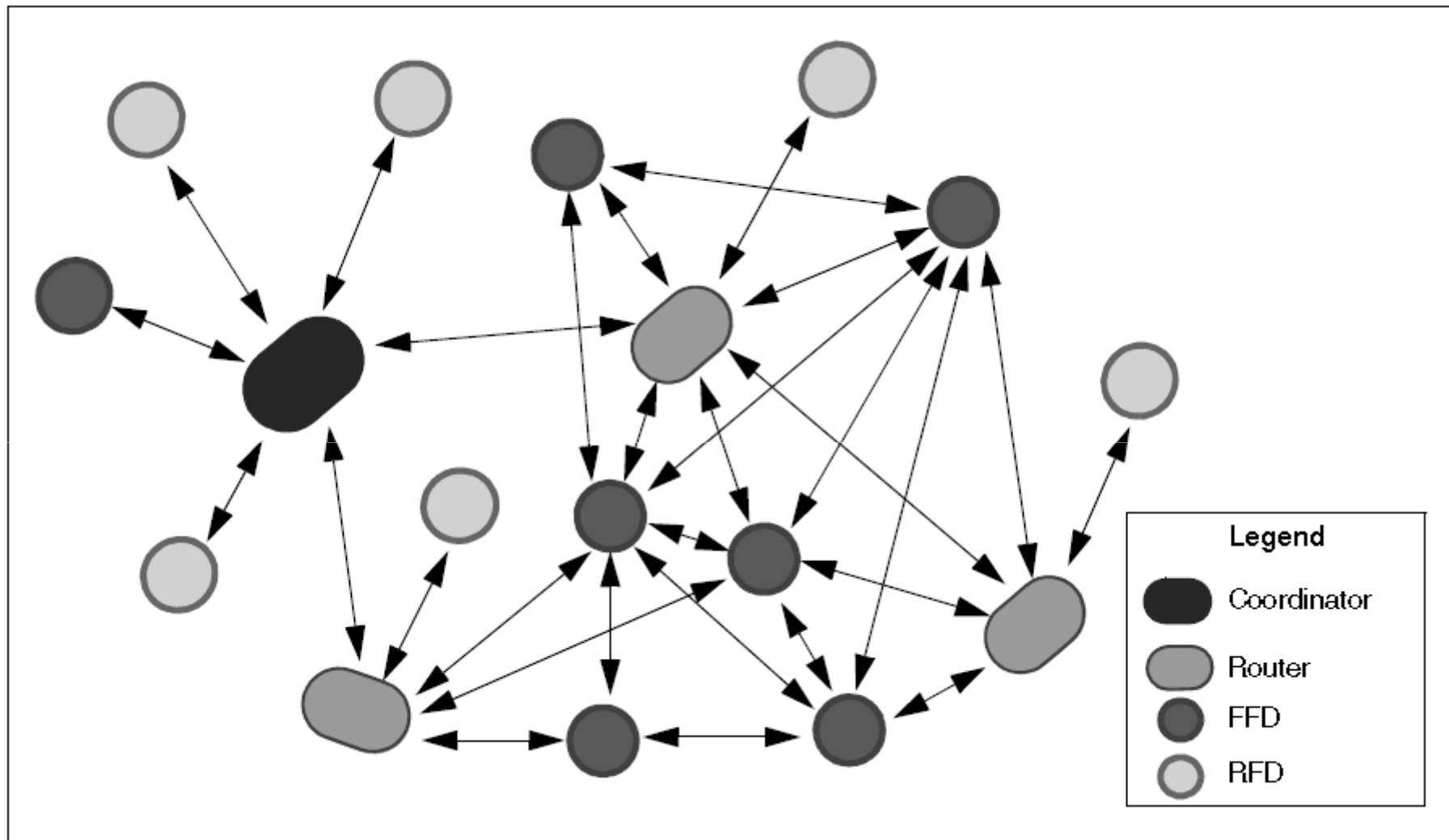
- Design of a Access Control System
  - Wireless Mesh Network
  - Simple generic design, easy roll out
  - Simple Addressing
  - Low Data rate
  - Low Cost (Cheap)
  - Requires Mains Plug in
- 
- Do not require to interoperate with another system
  - Propriety Protocol
  - ISM band (Cheap)

# This is What We Want

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# We don't want this



# Solutions

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- **Generic Propriety protocol similar to the original protocol, but using the IEEE802.15.4 standards.**
- **All device are the same Full Function Device (FFD)**
- **Every unit is capable of routing data**



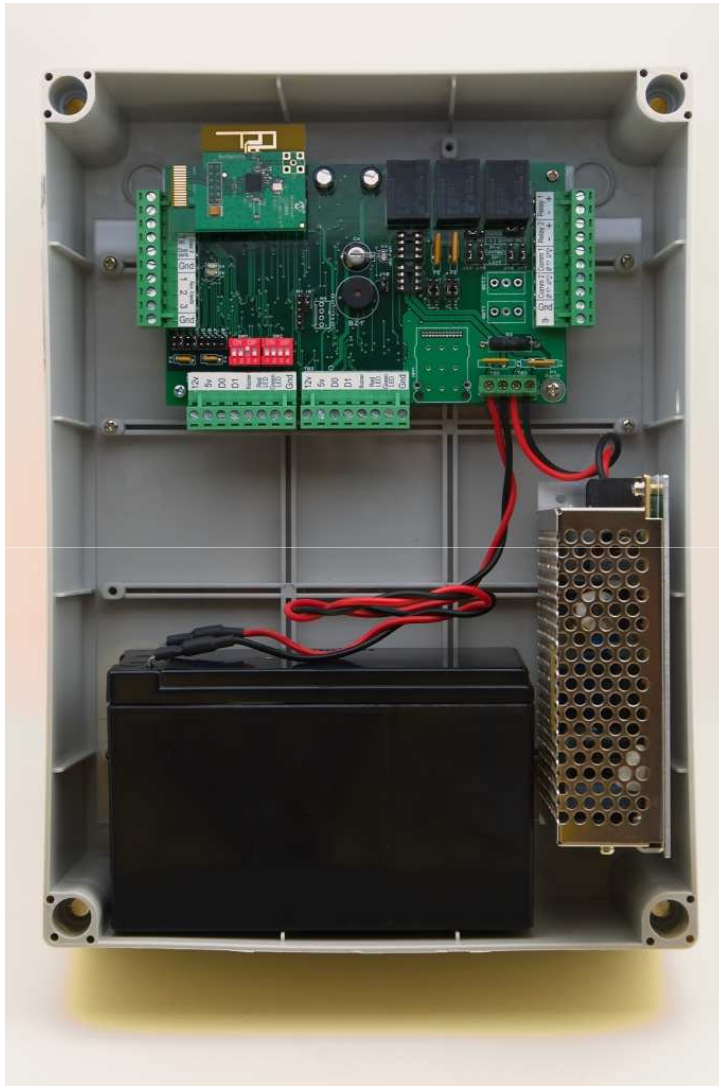
**Can we get a IEEE802.15.4 sensor network to work without having the complexity?**

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**THIS IS WHAT WE HAVE DONE**

# Lattice Wireless Access Control System

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- TWO DOORS CONTROLLER
- TWO READERS
- SUPPORT ANY WIEGAND FORMAT READERS
- SUPPORT SERIAL READERS
- BUILT IN BATTERY CHARGER
- WIRELESS COMMUNICATION
- RS485/TCPIP (OPTIONAL)
- NON VOLATILE FLASH RAM. 10 YEARS DATA RETENTION
- LOW HEAT OUTPUT DESIGN

# Wireless PCI (wPCI)

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Interface to Server

- USB type interface
- Serial RS485 interface
- Ethernet Interface (optional)
- IEEE 802.15.4 Standard



RAIN TAG

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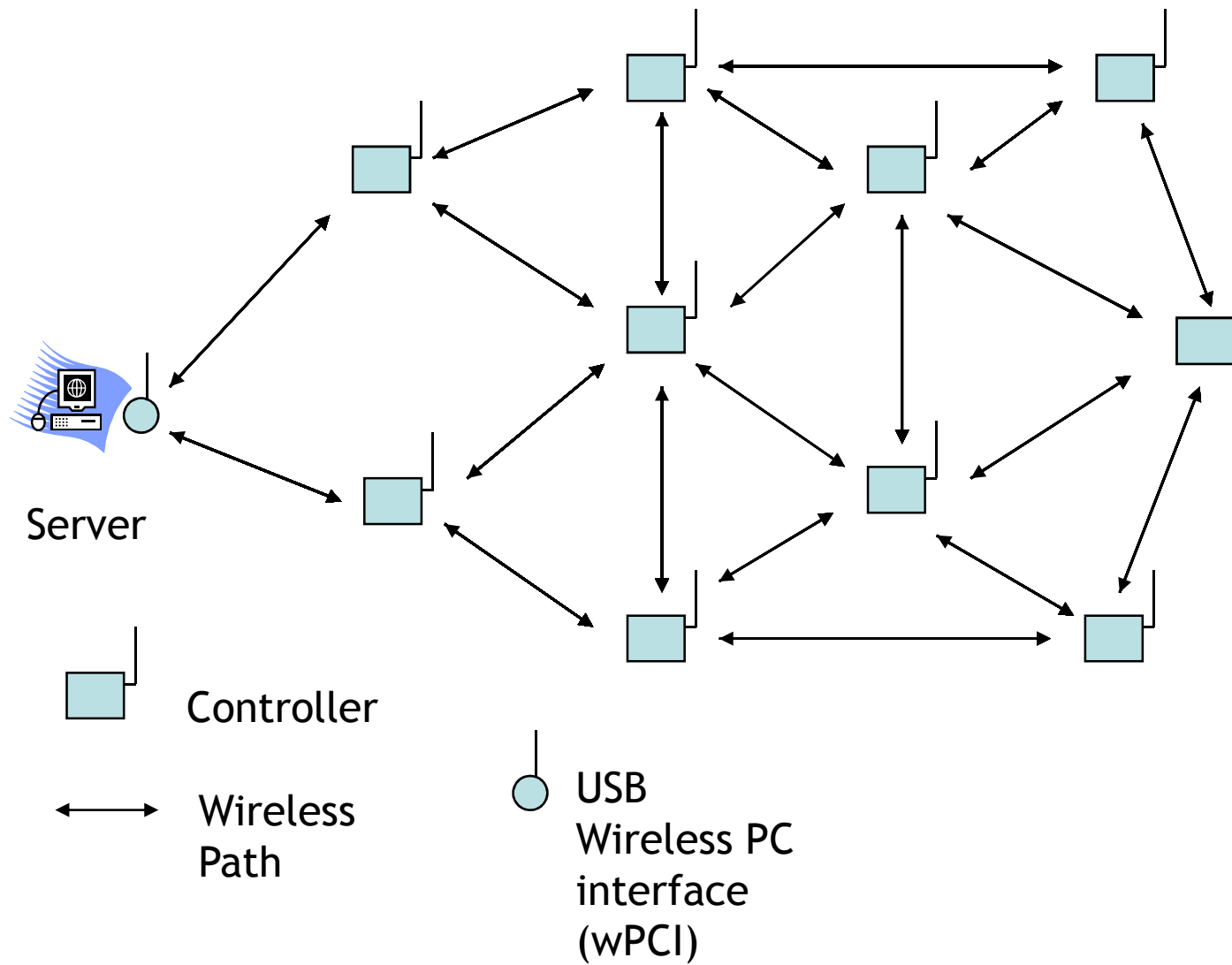
# Wireless Car Park Reader



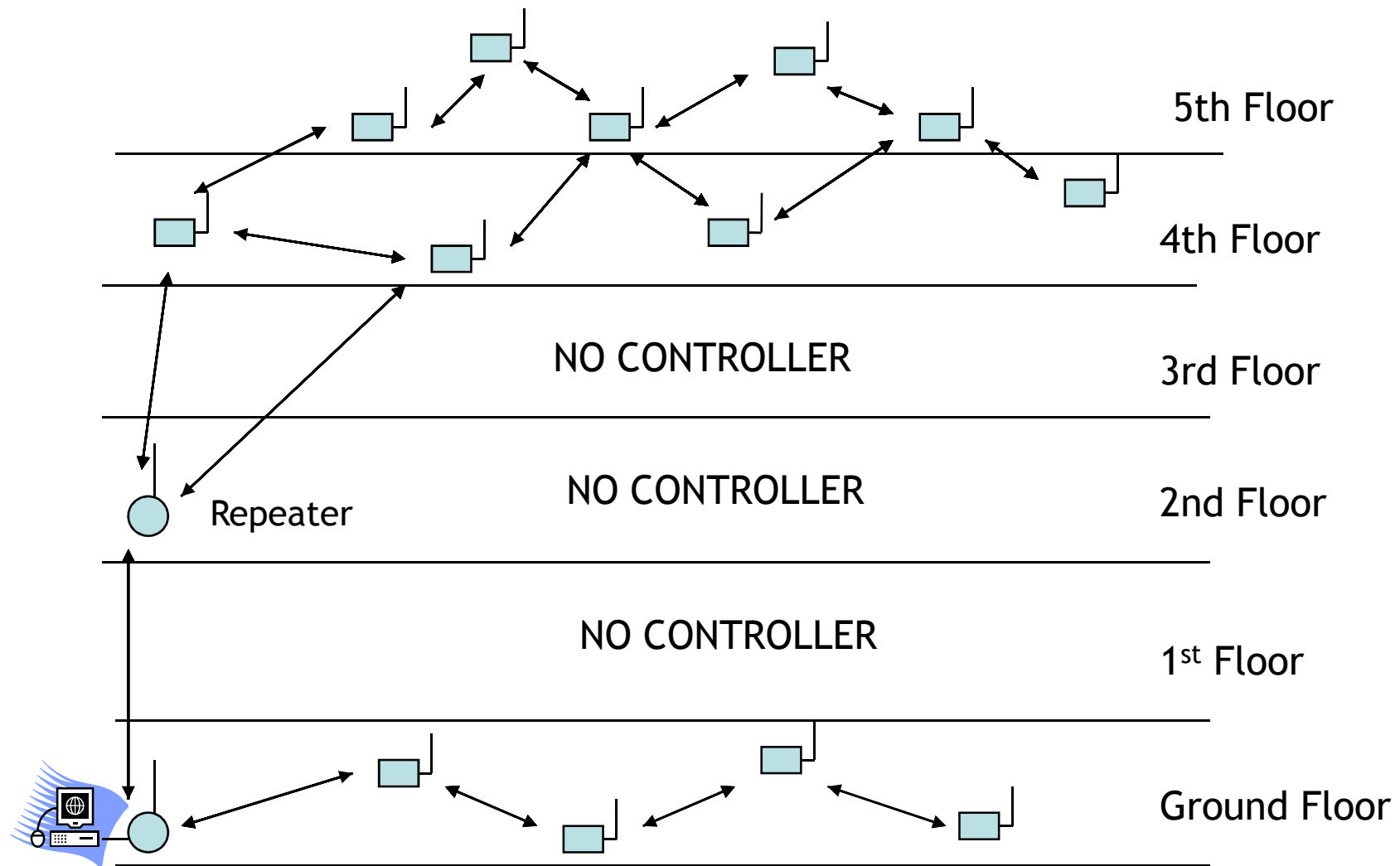
LONG RANGE ACTIVE TAG



# WIRELESS MESH NETWORKING



# Typical Building Layout



# True Wireless Sensor Network

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## ■ Requirements

- Battery Power Sensors for Security
- Reed Switch and Motion Sensor
- Power by 2 AAA size battery
- Size - As small as possible.
- Response Time < 5 secs
- Battery Life Span 2 to 5 years (or longer)
- Alternate Power Source
- Each Sensor is an extension for another sensor (mesh network)

# eRTLS Equipment Tag

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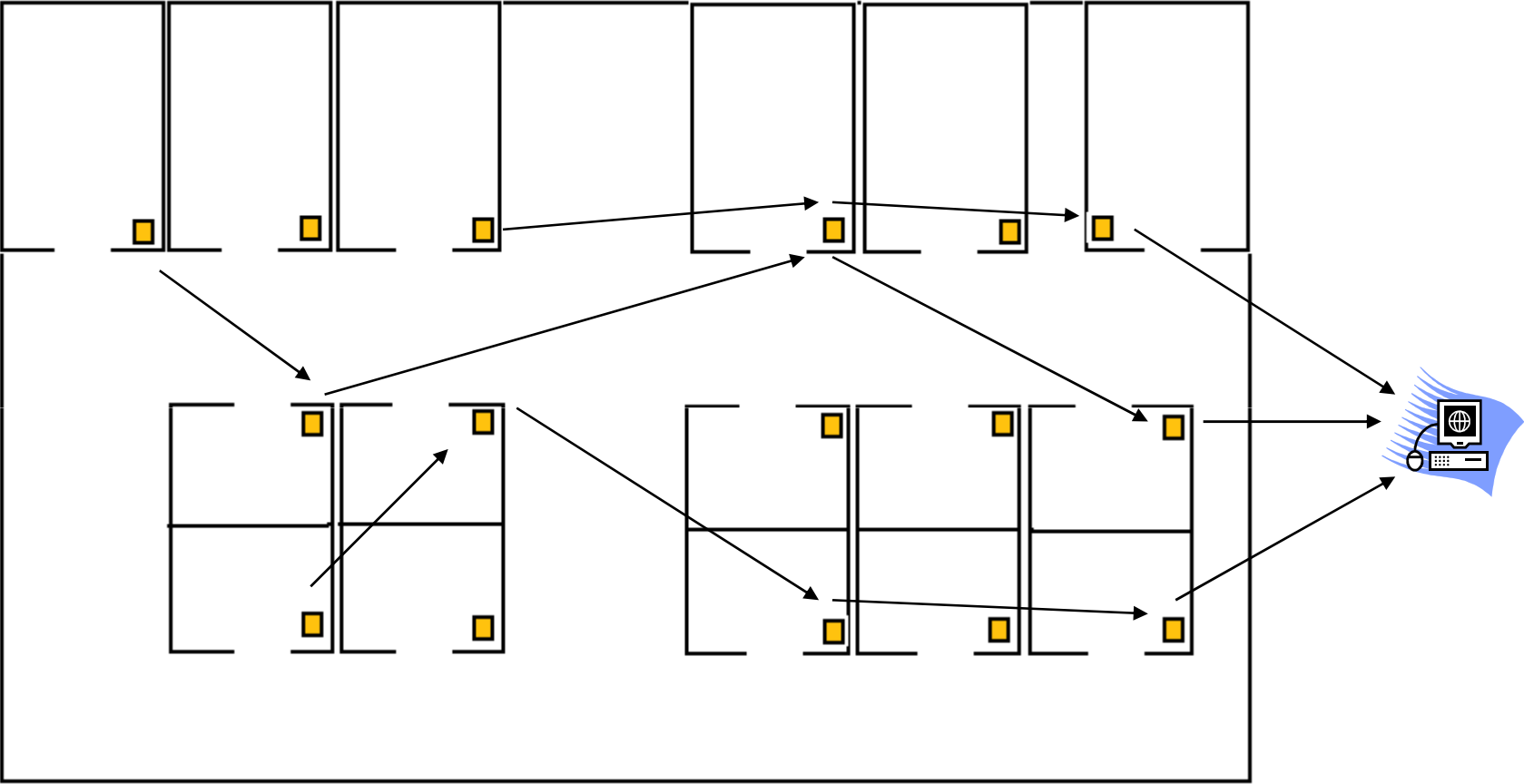
## Lattice Wireless™ eTAG

### Specifications

- IEEE 802.15.4 Wireless Standard
- Frequency 2.45Ghz
- Operating Temperature: 0 – 60C
- Power 2 AAA size batteries, Solar power.
- Data Transmission Distance: 50meters
- Built in Motion Sensor
- Tracking Up to 20 beacons.
- Sleep mode consumption 10uA.
- Wake consumption 5mA
- Battery life: Typical 2 to 5 years depending on usage



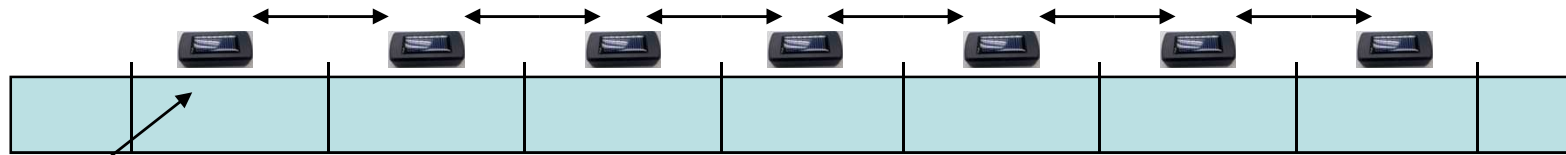
# Internal Intruder Detection (Mesh Networking)



# Perimeter Intrusion

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Wireless Hops



Sensors are 50m Apart



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# REAL TIME LOCATION SYSTEM



[www.QuatisRTLS.com](http://www.QuatisRTLS.com)

# QUATIS Location System

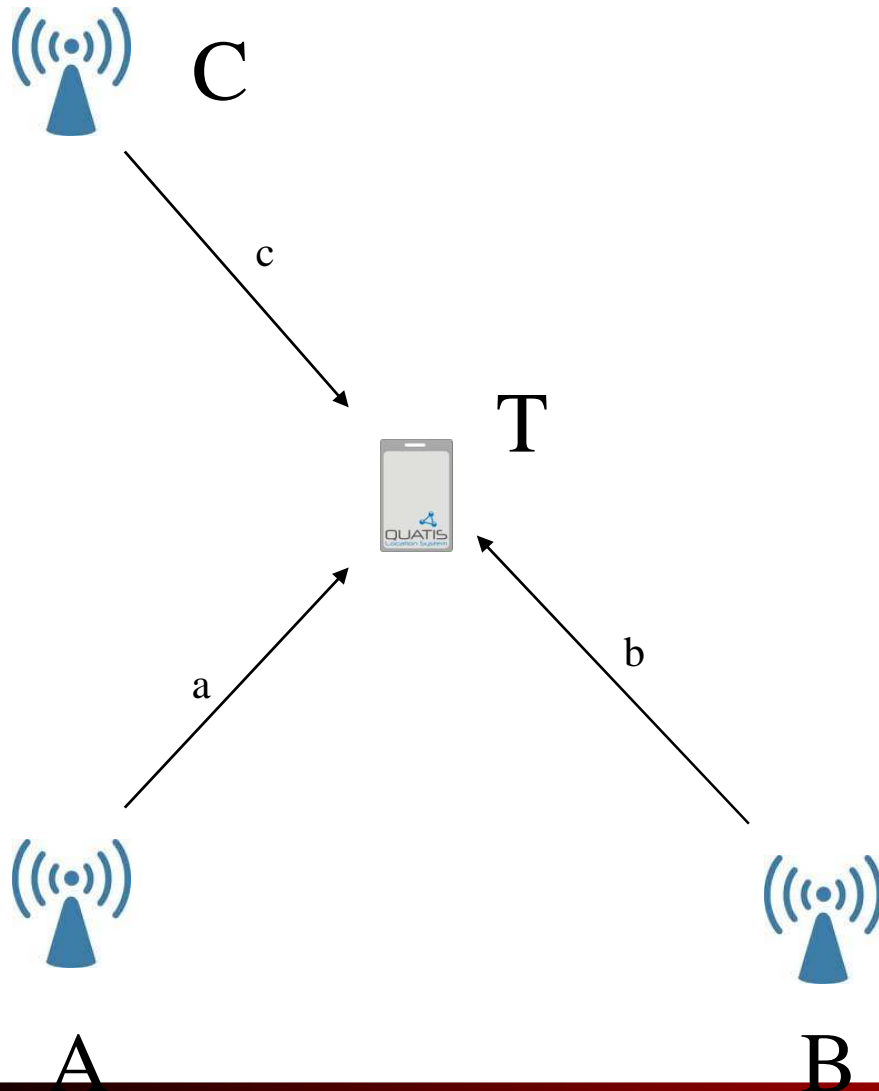
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## What is RTLS

- Real Time Location Tracking
- Tags are 'AWARE' of its own location.
- Location can be tracked and logged in real time
- Location of Tag is calculate by knowing distance to at least 3 Beacons
- Distance to Beacon is estimated by using RSSI (Receiver Signal Strength Indicator) and TDOA (Time Delay on Arrival)

## HOW IT WORKS

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Beacon A, B, C – **Location known**

Tag T – **Location Unknown**

Tag determines distance a, b and c

Once a,b, c is known, location T can be calculated.

For higher accuracy, we can add more beacons

Accuracy up to 2m

# QUATIS Location System

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## Asset Tag Qt55SP

### Specifications

- Frequency 2.45Ghz
- Processor 32bit RISC
- Operating Temperature: 0 – 60C
- Power : 2 AAA size batteries, Solar power.
- Indication: Buzzer and LED
- Battery Life (Indoor 3-4years, Outdoor 6-10 years)
- Data Transmission Distance:  
Line of Sight 200meters, Indoors 50meters
- Built in Motion Sensor, Magnetic Contact and Temperature sensor
- Accuracy : approx 2 meters
- Tracking Up to 20 beacons.
- Dimensions :

### Application:

Tag is designed for large equipment. It uses standard batteries, augmented with solar panel to extend the life of the batteries. Optionally this tag can be used for security monitoring and temperature monitoring.

# QUATIS Location System

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## Application:

Tag is designed to be worn by any personnel. The built in Mifare™ Smartcard allows compatibility to most high-end Door Access Control System. This Tag size is similar to standard card with a thickness of only 6mm. Tag can be customized with the user Photo ID

## Personnel Tag Qt80PT Specifications

- Frequency 2.45Ghz
- Processor: 32bit RISC
- Built in Mifare™ : Dual Technology
- Operating Temperature: 0 – 60C
- Power CR2032. Replaceable
- Data Transmission Distance:  
Line of Sight: 200meters, Indoor 50meters
- Built in Motion Sensor, temperature Sensor
- Battery life: Typical 2 to 5 years depending on usage
- Accuracy: Approx 2 meters
- Dimensions: 86 X 54 X 6mm
- Photo ID

# QUATIS Location System

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## Application:

Tag is designed to be embedded into equipment like Laptop for tracking purposes. It has a small form factor and a thickness of only 3mm. Equipment must be non metallic. Battery life span of 4 to 5 years will last the lifetime of most equipment tagged.

## Embedded Tag Qt20ET

### Specifications

- Frequency 2.45Ghz
- Processor: 32bit RISC
- Operating Temperature: 0 – 60C
- Power CR2032. Replaceable
- Data Transmission Distance:

Line of Sight: 200meters, Indoor 50meters

- Built in Motion Sensor, temperature Sensor
- Battery life: Typical 4 to 5 years depending on usage
- Accuracy: approx 2 meters
- Dimensions: 60 x 30 x 3mm
- Photo ID

# QUATIS Location System

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## Beacon Qt1000BT

### Specifications

- Frequency 2.45Ghz
- Processor: 32bit RISC
- Operating Temperature: 0 – 60C
- Power: 240AC with power adaptor
- Data Transmission Distance:

Line of Sight: 200meters, Indoor 50meters

- Data Communication Node
- Transmission Power: 10mW

### Functions:

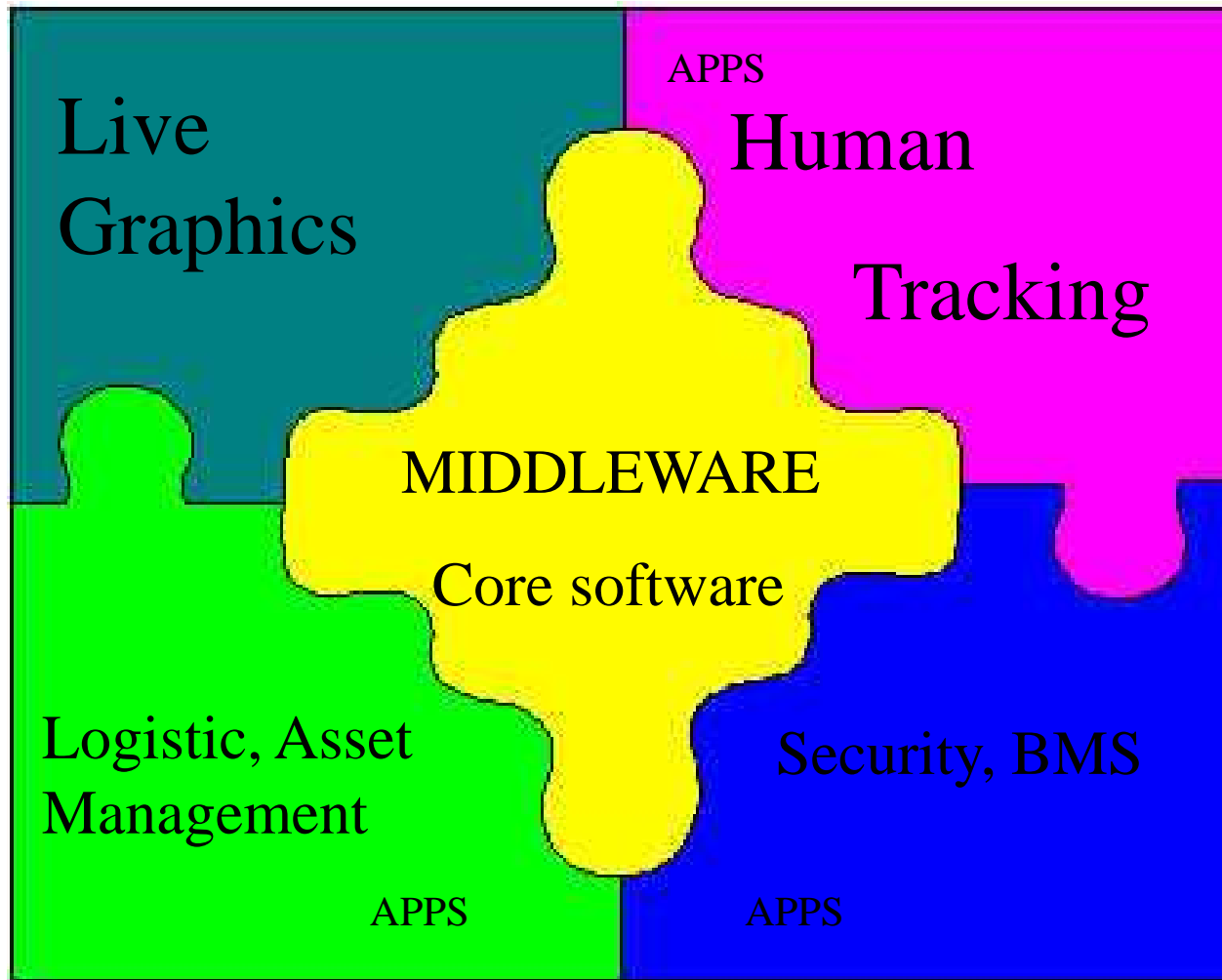
Beacons are fixed location wireless emitter which acts as a reference for the Location Tags. The Tags will estimates the distance to each beacons in order to calculate its locations. At least 3 beacons are required for a 2D location.

## QUATIS ON TRACK

Location Tracking Middleware

# QUATIS Location System

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# QUATIS Location System

The floor plan shows numerous booths including: IRC, MAGNET, MK-FOUR, MAXITULIN, CTI, EAMSC, NEURAL, SATRONEC, OYL, NIMROD, STRATEL, SAMSUNG, SENSORLINK, MICRO ENGINE, CELTECH, SAXCO, PANASONIC, VIEWTECH, RCG, ELID, ALARM AUTOMATION, LOTUS, POWERFENCE, SAMSUNG, PAN DIGITAL, VIDEOSOFT, SH Tan, VIVO SIAGA SEC, HOME TOUCH, AAC, PICASSO, FINGER TEC, CONTROL POINT, ASG, ZHEJIANG DONGYUE, MICRO ID, KESTRONICS, GAMMA, BLUGUARD, CYNICS, INDEXCOM, PROKITS, MESHTEC, FIKE, AAS, CARSAFE, INTELLIGENT NETWORK, OML, SUPER PAGES, ARMOR ECH, BLUECARD, INFORMESCO, D'NONCE, OML, SUPER PAGES, CARSAFE, INTELLIGENT NETWORK, ASS, GOLD GATE, RADMIK, NETEON, LIT TECH, GAMMA, BLUGUARD, CYNICS, INDEXCOM, DEA, ALC TECH.

**Tags Information**

TagRefNo	Name	Temperature	BatteryLife	LastKnowLocation	LastActiveTime
H0001	SH Tan	25.0	High	KLCC Exhibition Hall	2010/05/31 05.11.22 PM
H0002	Stewart	25.0	High	KLCC Exhibition Hall	2010/05/31 05.11.23 PM
H0003	Chooi	25.0	High	KLCC Exhibition Hall	2010/05/31 05.11.25 PM
H0004	Sew Ling	25.0	Medium	KLCC Exhibition Hall	2010/05/31 05.11.26 PM
H0005	David	25.0	Low	KLCC Exhibition Hall	2010/05/31 05.11.38 PM
H0006	Ann	25.0	High	KLCC Exhibition Hall	2010/05/31 05.11.38 PM
H0007	Seah	25.0	Medium	KLCC Exhibition Hall	2010/05/31 05.11.38 PM

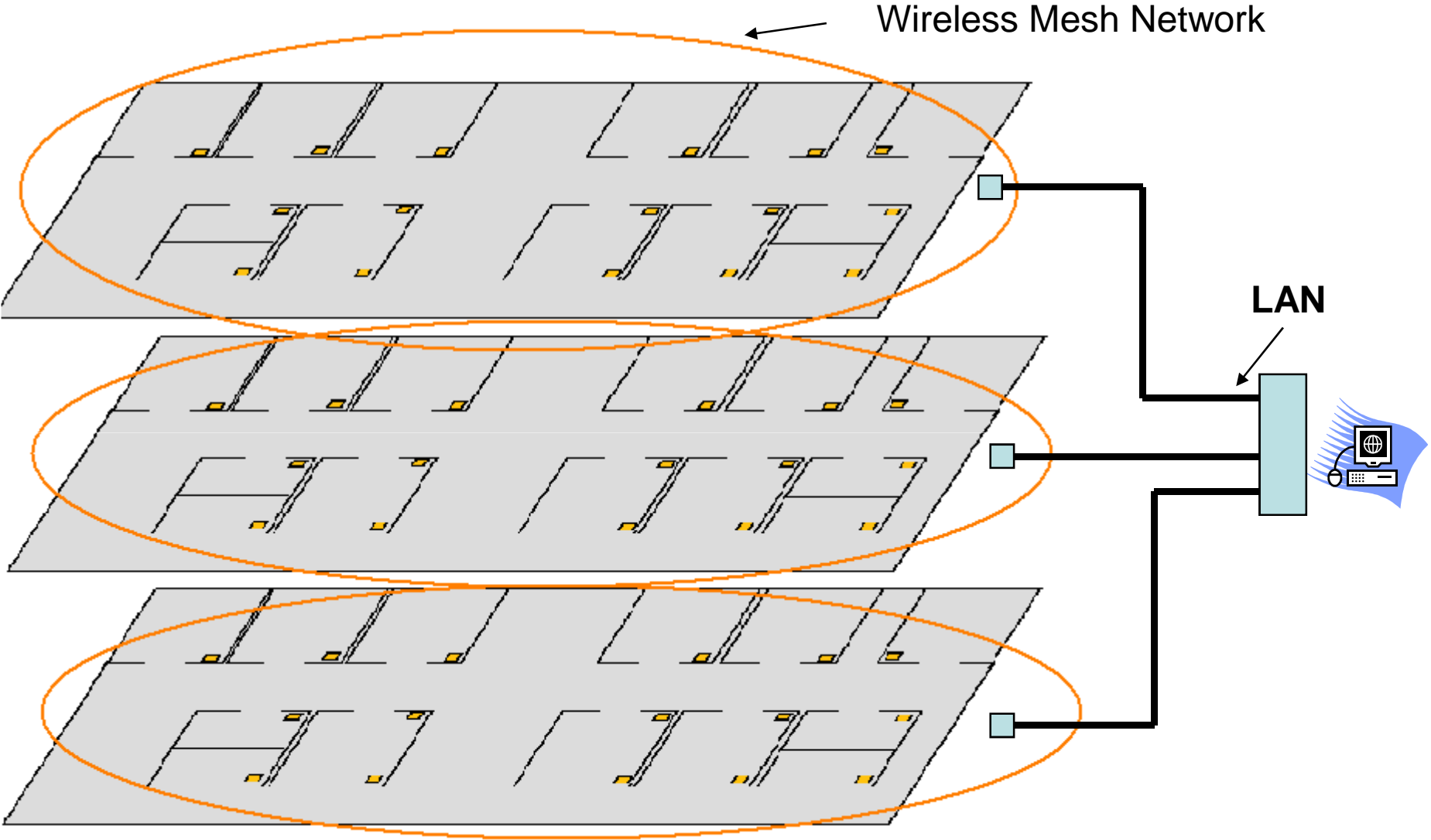
**Trace Tag**

Start Trace

Stop Trace

Show Tag Name

# System Overview



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*People have a tendency to overestimate technology  
in the short term, and underestimate it in  
the long term.*

*Bill Gates*

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# FAQ

# FAQ

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## What if the Wireless Communication Fails?

- There will be times when there are strong interference on the wireless radio spectrum
- The Lattice Wireless Access Control will continue to work without any degradation as the database is kept in the controller. Only the transactions will be delayed until the wireless recovers. Its robust protocol will ensure that all the transactions are downloaded accurately.
- If installation of cards are required when the communication fails, the software will create a background task which will wait for the wireless to recover and then install the cards. Once successful, the action will be reported to the user

## FAQ (cont...)

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What is the baud rate of the wireless network?

- 250kbps

How Many Controllers can be connected in a single Network?

- 250 Controllers

## FAQ (cont...)

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If there are so many controllers, how long does it take for the transaction to arrives at the Server?

- The Server can poll up to 5 controllers per second. For 250 controllers, it takes up to 50 seconds to poll every controller.
- The controllers have a broadcast mode which can send the transactions to the Server instantly without polling. The delay is less that 1 second. The Server will still poll the controller to make sure that it is still connected.

## FAQ (cont...)

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# How secure is the Wireless Communication?

- The wireless uses AES-128 bits encryption. This is the same encryption used by the US government. (see Wikipedia)
- A range of auto generated rotating Encryption Keys are used by the lattice controller.
- Beside encryption, all data packet have sequence number and the system will detect a wrong sequence number.
- Controller and wPCI have unique customer code which prevents access to another network controllers.
- The Wireless is NOT WiFi, which makes it harder to hack.

# Why is the Wireless System Low Cost?

IEEE 802.15.4 is a low power radio standard. The transceiver consists of simple low power radio circuits. Most of the network routing capability are implemented in the controller software.

Why no one else have such a system?

- The IEEE 802.15.4 was only rectified in 2006. Before then there are no similar standard.
- Only recently the microprocessor have become powerful enough to support such system.

## FAQ (cont...)

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# What are the advantages of this Wireless Mesh Networking

- No complicated communication wiring. This saves 40-60% in implementation cost.
- Reduce commissioning time.
- Quick Implementation as only AC wiring is required
- No messy site
- Reduce Lightning Damages. As there are no communication wiring, lightning surges are significantly reduced.
- Easy maintenance. No wiring to troubleshoot. Just change controller.
- Easy Expandability. Just add new door. No wiring

## FAQ (cont...)

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What if there is a controller which is far away and there are no other controller nearby?

- The Wireless PCI (wPCI) can be used as a node to extend the wireless reach.

## FAQ (cont...)

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What prevents a neighboring network from connecting to another network within range?

- Lattice controller have a built in unique customer code which only connects to controller with similar code.
- There are also selectable wireless channel to prevent interconnection.

## Conclusion

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# Paradigm Shift in Access Control System Design

In the near future, all building related systems will be based on wireless technology

We are at the dawn of the new wireless age.