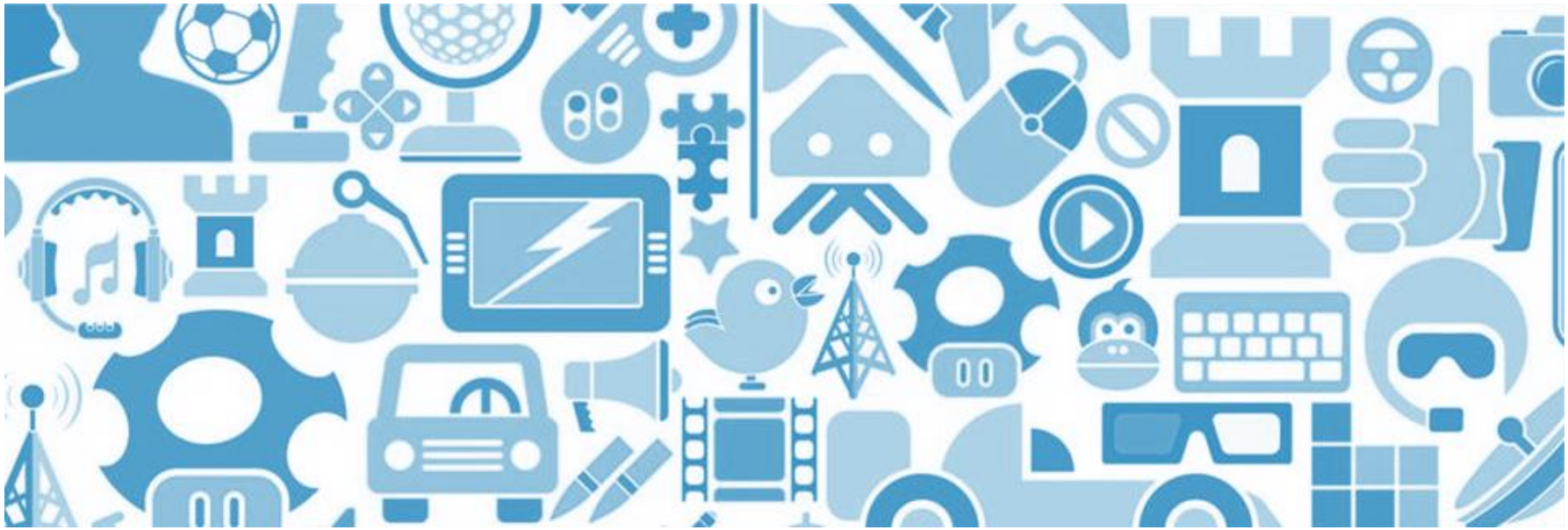


IoT LowPAN Networks

- Mesh or not to mesh!

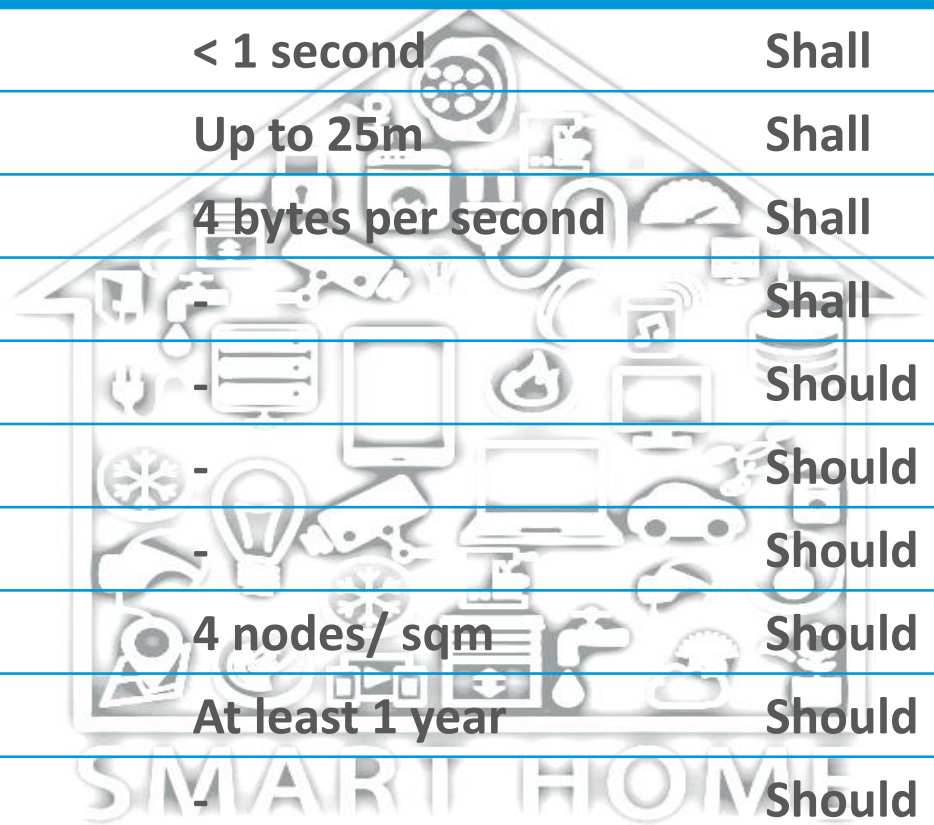
NORDIC SEMICONDUCTOR

Ioannis Glaropoulos
Krishna Shingala


SMART HOME

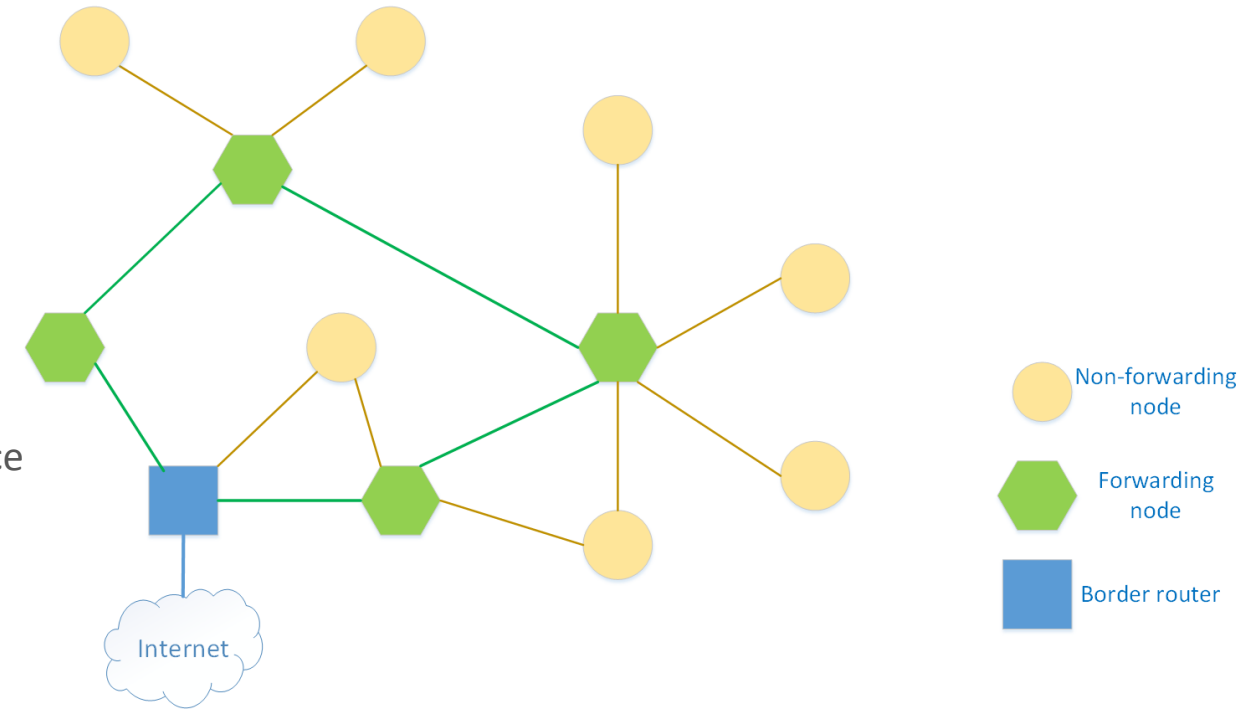
Requirements

Metric	Range	Level
Response	< 1 second	Shall
Range	Up to 25m	Shall
Throughput	4 bytes per second	Shall
Secure	-	Shall
Interoperable	-	Should
Robust	-	Should
Scalable	-	Should
Density	4 nodes/ sqm	Should
Battery life	At least 1 year	Should
Ease of use	-	Should
Firmware Upgrade	-	Should



Mesh: A necessity

- Physical system limitations
  - Wide network area
  - Transmission power
  - Receiver sensitivity
  - Link quality
    - Cross-network interfernce
    - Attenuation
  - Battery-operated devices
    - Consumption reduction



Mesh: Let's go multi-hop

- Ongoing research for two decades
  - 1000+ research papers (ACM DL, IEEExplore, Elsevier, Springer)
  - PHY, LL, Routing and cross-layer optimizations
- Standardization approaches
  - AODV networks (2002 -)
  - RPL networks (2005 -)
  - Thread (2015 -)
  - BLE Mesh
  - ....
- (Open-source) mesh stacks
  - Tiny OS
  - RIOT
  - Contiki-OS
  - Mbed
  - ...

ARM mbed

RIOT

Contiki

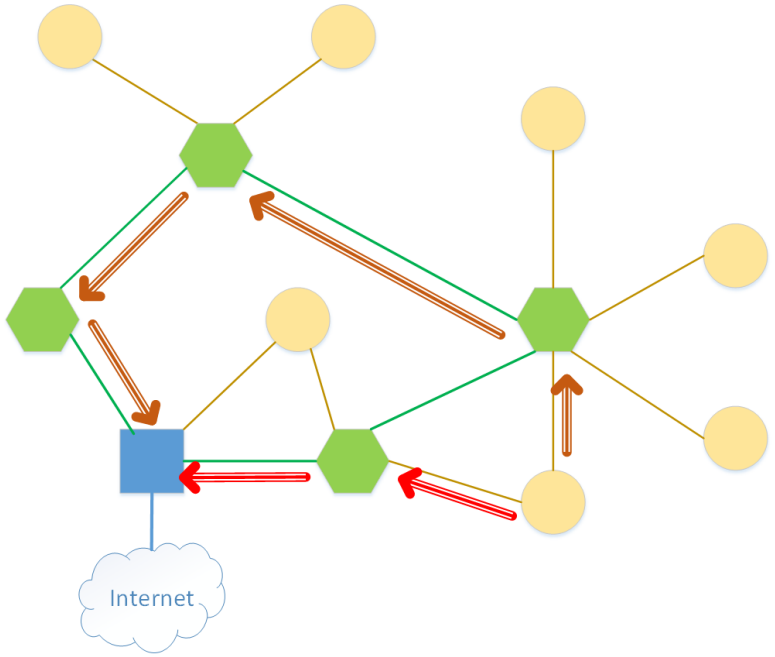
The Open Source OS for the Internet of Things

TinyOS

NORDIC SEMICONDUCTOR

Mesh: An IoT designer's choice

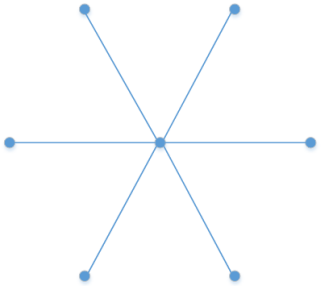
- Strong requirement for connectivity
- Node mobility
- Cost reduction
  - No back-bone network
  - Fewer gateways
- Security aspects
  - E.g. No sigle-point of failure
- Network performance?

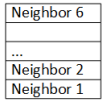


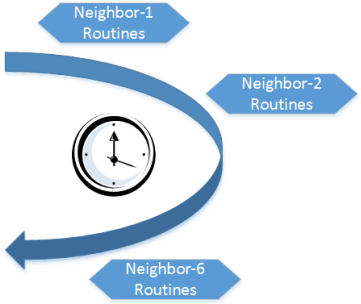
NORDIC SEMICONDUCTOR

Mesh: Winning aspects

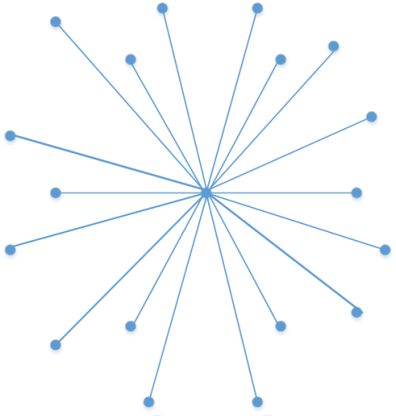
- High one-hop bandwidth
  - Spectrum re-usability
  - Lower interference, higher packet rates
  - Efficient medium access control
  - Scalability

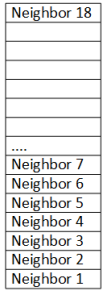


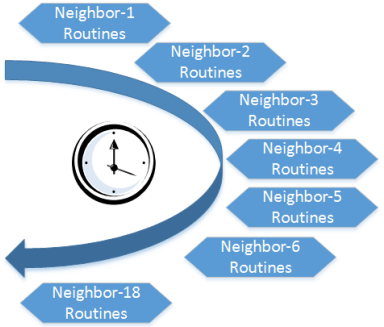




- Efficient network layer
  - Lower neighbor degree
    - Low signalling overhead (neighbor routines, routing maintentance etc.)
  - Self-organization, self-healing
  - Scalability
    - Node density
    - High traffic bursts







NORDIC SEMICONDUCTOR

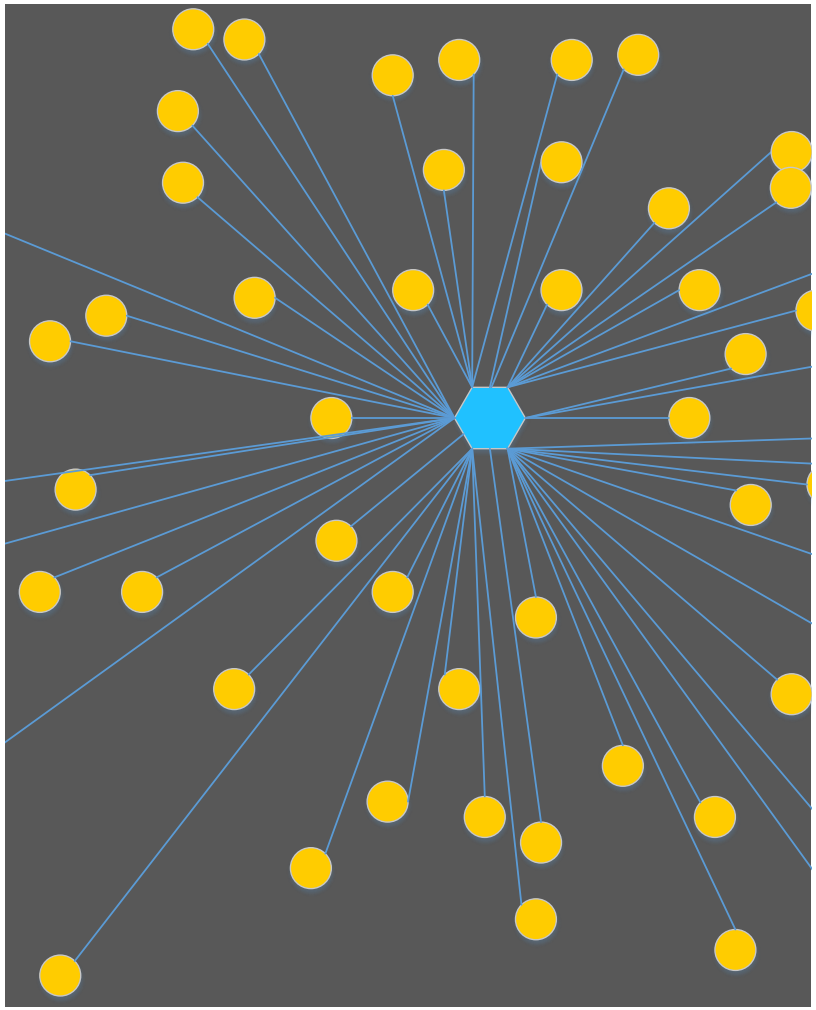
User Story

- I want a smart lighting at home -25 lights, 4 controllers.
- I want to control the system from work.
- One command, and all lights off!
- Controllers are mobile, battery powered; batteries should last a year at least..!
- System should work always, just the same.

Engineer's Thoughts

- That's a mesh, finally!
- That's a mesh with a border router.
- Of course, multicast in mesh.
- Sleepy end nodes, why not!
- RTFM! Right setup, expected behavior!

NORDIC SEMICONDUCTOR

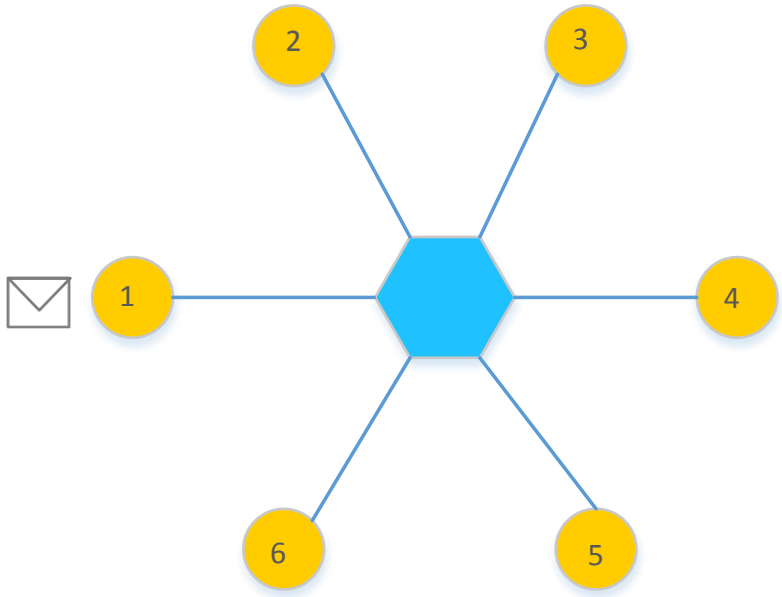


Why not star?

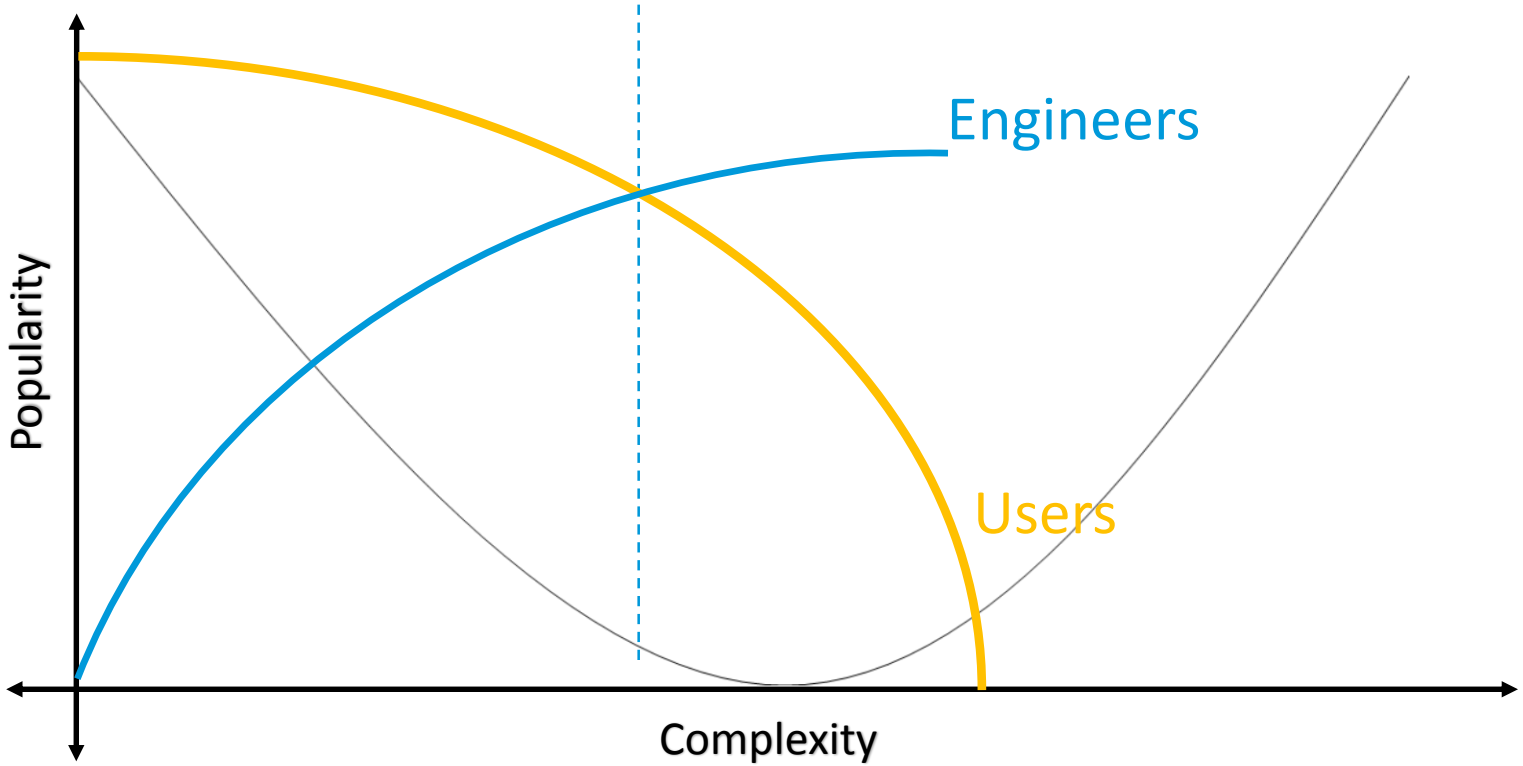
- Requires
  - Longer range
  - Good scheduling
  - Some Innovation
- Benefits
  - Lower complexity
  - Lower cost
  - Interoperable
  - Ease of Use
  - Better battery life..(?)

The Star: Not Omnipotent!

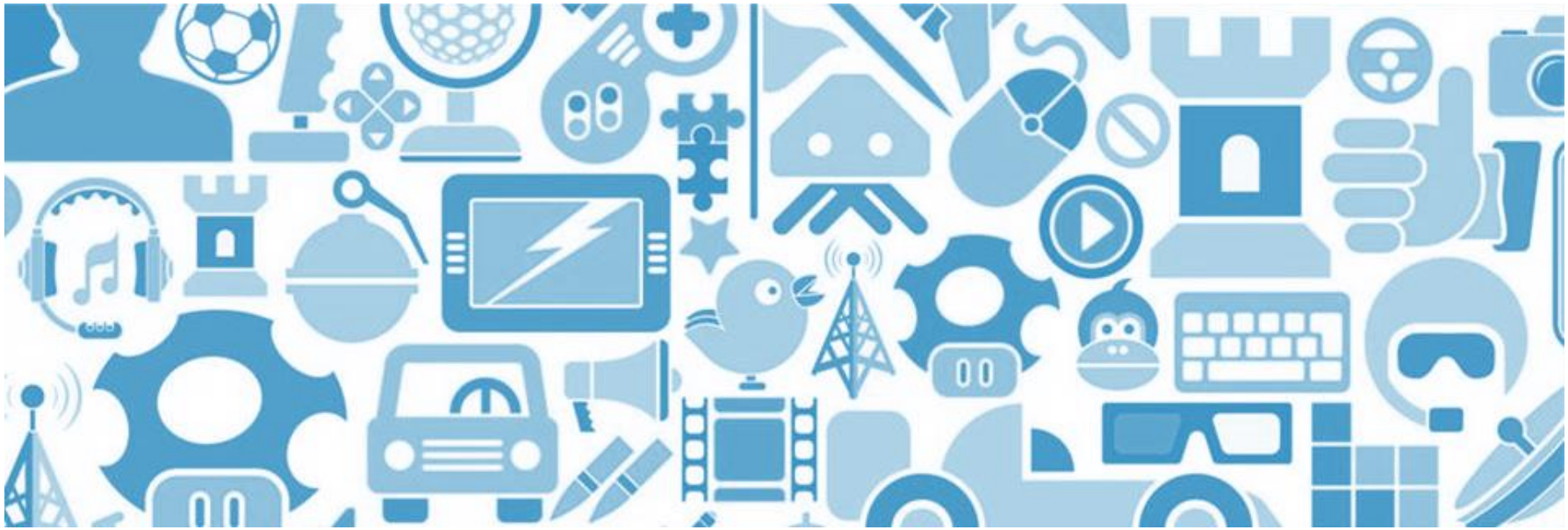
- The multicast problem.
- Single point of failure.
- Fading.
- Limits bandwidth or increases power.



Lets Keep it Simple!



NORDIC SEMICONDUCTOR

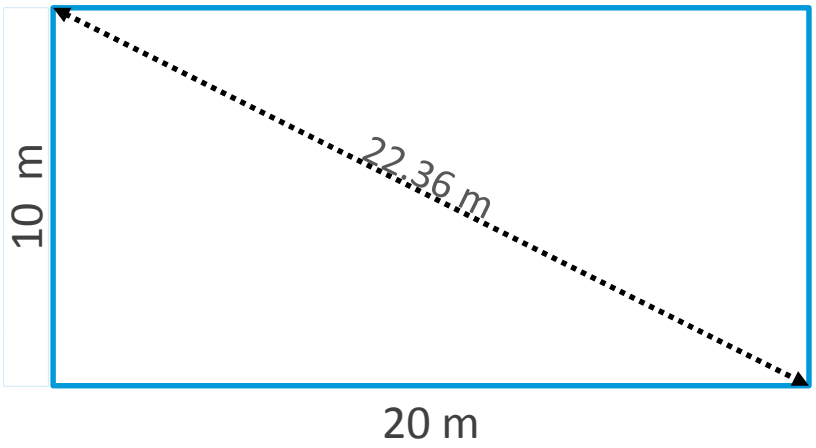


Open Discussion

NORDIC SEMICONDUCTOR

Range calculation

- Assume size of home to be 200 sqm – lets fix the dimensions to be 20x10.
- Therefore distance between farthest nodes is ~ 22.36 meters.
- Assuming a start topology, with the router placed at the center, the needed range is ~11 meters.



$$10^2 + 20^2 = 22.36^2$$

Volume calculation

- Lights per sqm = Lumen recommended per sqm/ Lumen provided by each light.
  - Here, 150 lumen recommended per sqm.
  - A 4W LED provides ~50 lumen.
  - Therefore, **3 LEDs per sqm**.
- Light nodes for 200 sqm = 200 * 3 = **600 LED nodes**.
- Controllers needed for the area assuming each controller controls 4 LEDs = 600/4 = **150 controllers**.
- Therefore, (LEDs + controllers) in a 200 sqm area = (600 + 150) = **750 nodes**.
- Assuming other environmental sensors may be used, **~800 nodes** in a 200 sqm area may be realistic. This means about **4 nodes IoT nodes per sqm.**

Hop count calculation

- Assuming each node is the mesh network is configured for a range of ~1 m, number of nodes between two farthest nodes is (~ 2 * distance - 2) = 2 * 23 -2 = ~44 nodes.
- Therefore the minimum number of hops between the two farthest nodes is **~ 44 nodes.**