Scaling Wireless Sensor Networks to the Next Trillion Devices

Stanford | SystemXAlliance

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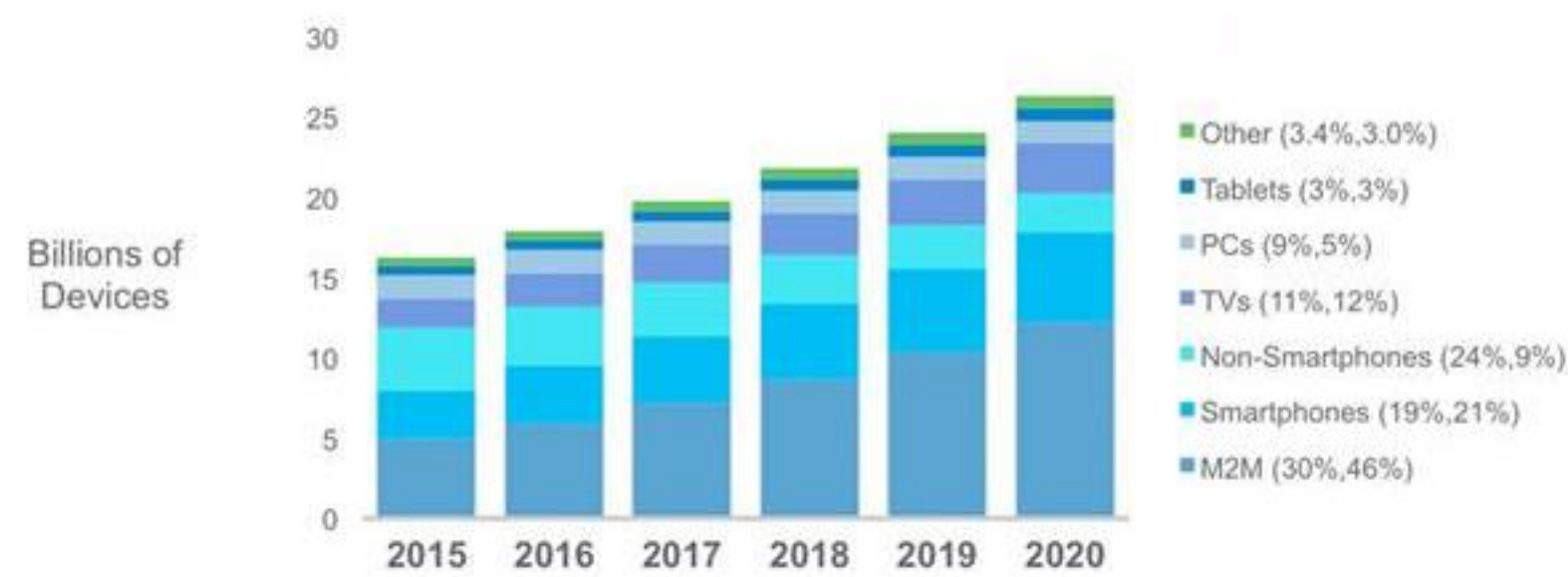
Increasing Interconnectivity

Fig. 1. Global growth of wirelessly-connected devices, projected to the end of the decade [1].
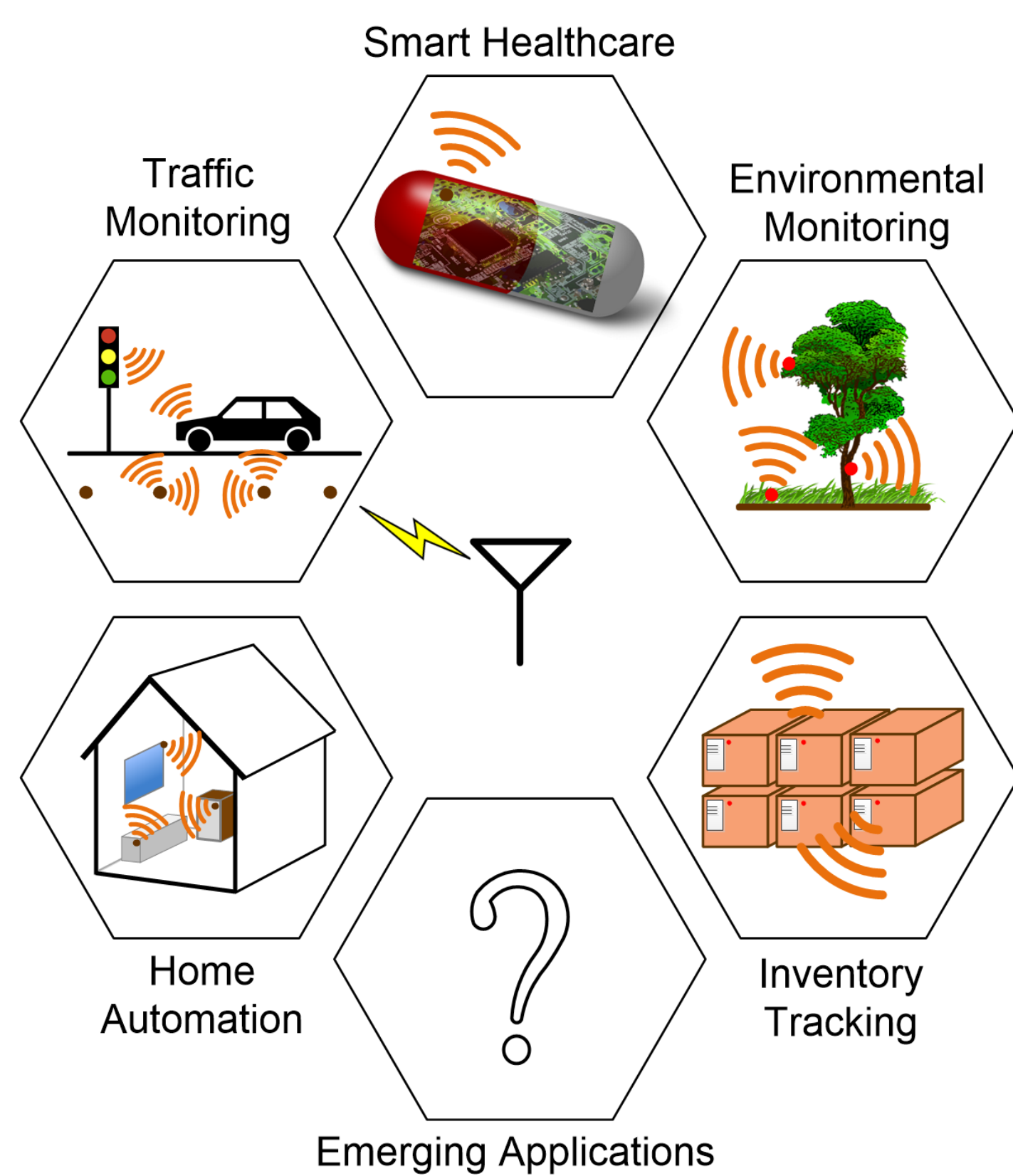

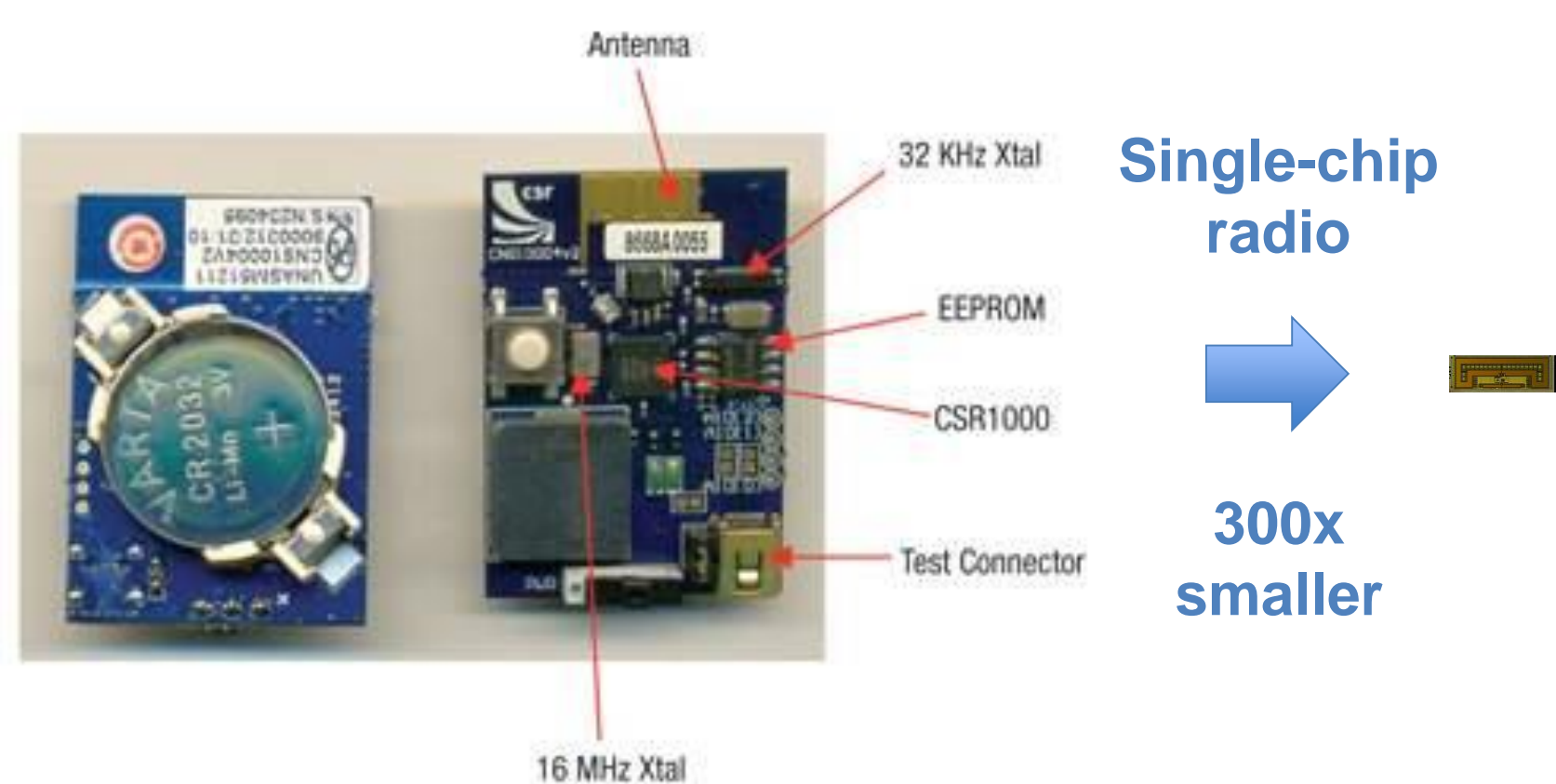Fig. 2. Scenarios showing applications of mm-sized IoE sensors [2].

Fig. 3. Envisioned shrinking of wireless sensor nodes [3].

- **Vision**: interconnectivity of trillions of sensors for the **Internet of Everything** (IoE)

- **Challenges**
  - Unreliable on-chip clocks for communication
  - Massive multiple access
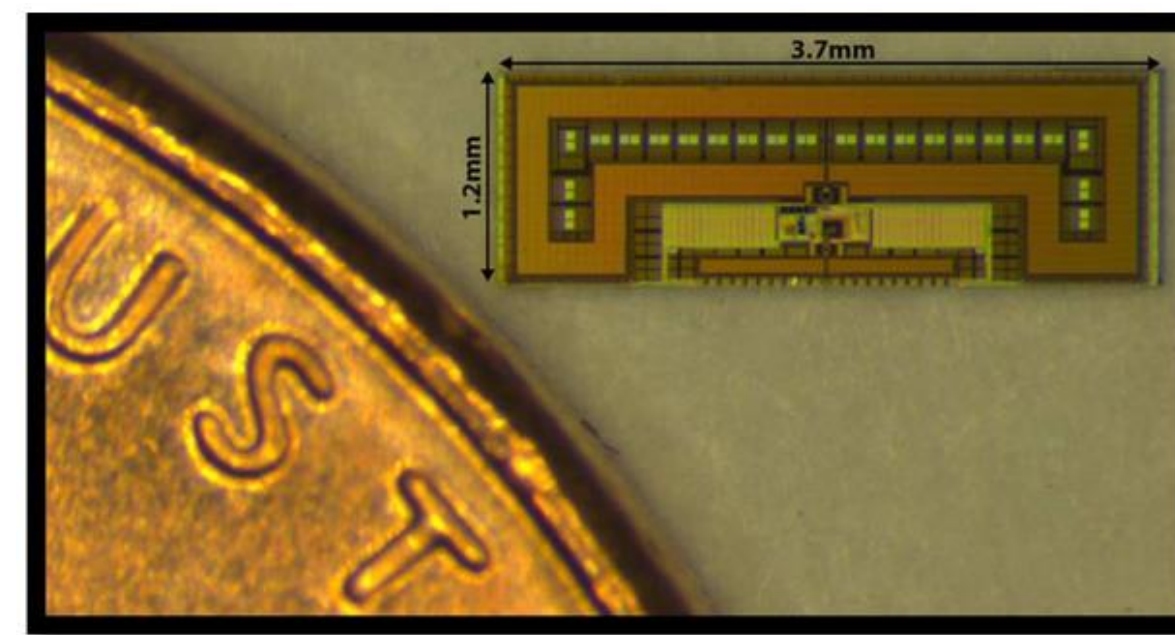 - Wireless power transfer and low-power circuit design

An Ant-Sized Radio

Fig. 4. Die photo of our standalone mm-wave radio [4].

- **Entire radio integrated on a single 4.4 mm^2 chip**

  - 24 GHz RX wireless power and data
  - 60 GHz TX data (M-PPM)
  - >12 Mbps aggregate data rate with <1.5 μW harvested power
  - 50 cm communication range
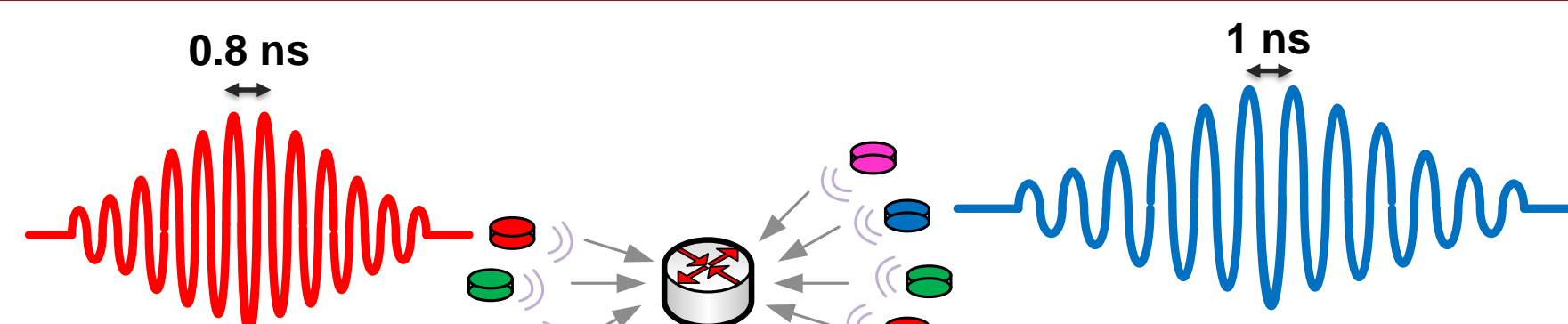
Unreliable Clocks and Energy
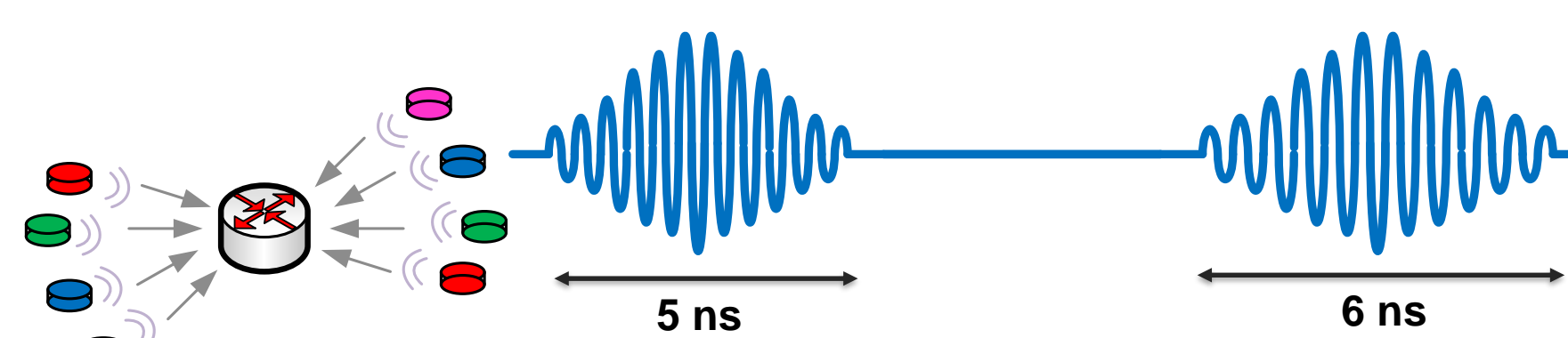

Fig. 5. Mismatched clocks due to clock drift.

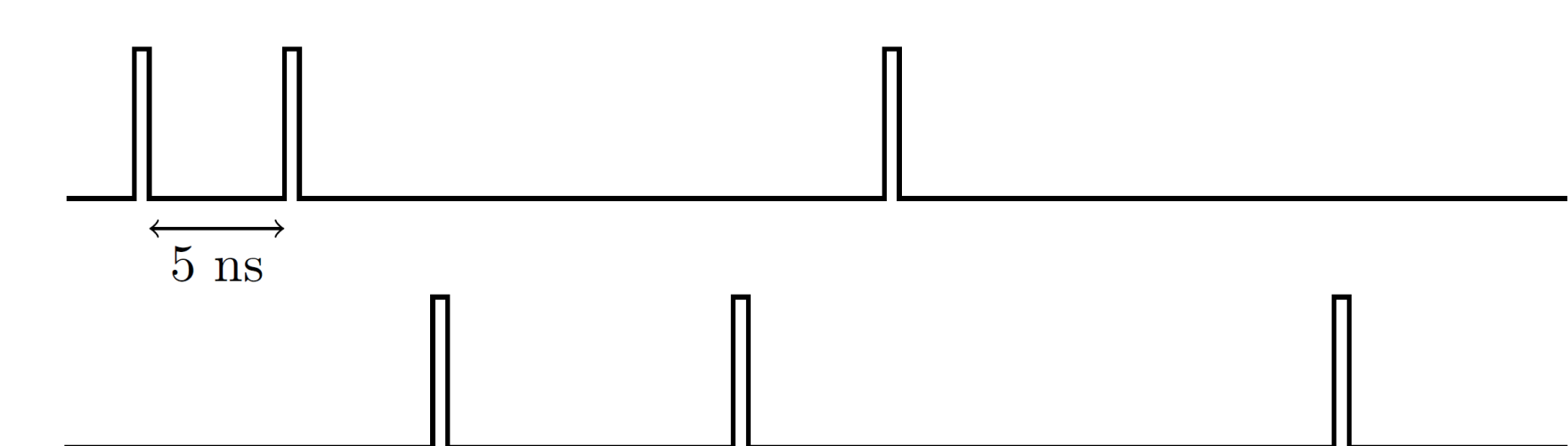Fig. 6. Limited data rate due to severe clock jitter.

Fig. 7. Top: existing clock and data recovery coding scheme; bottom: novel scheme with higher data rate.
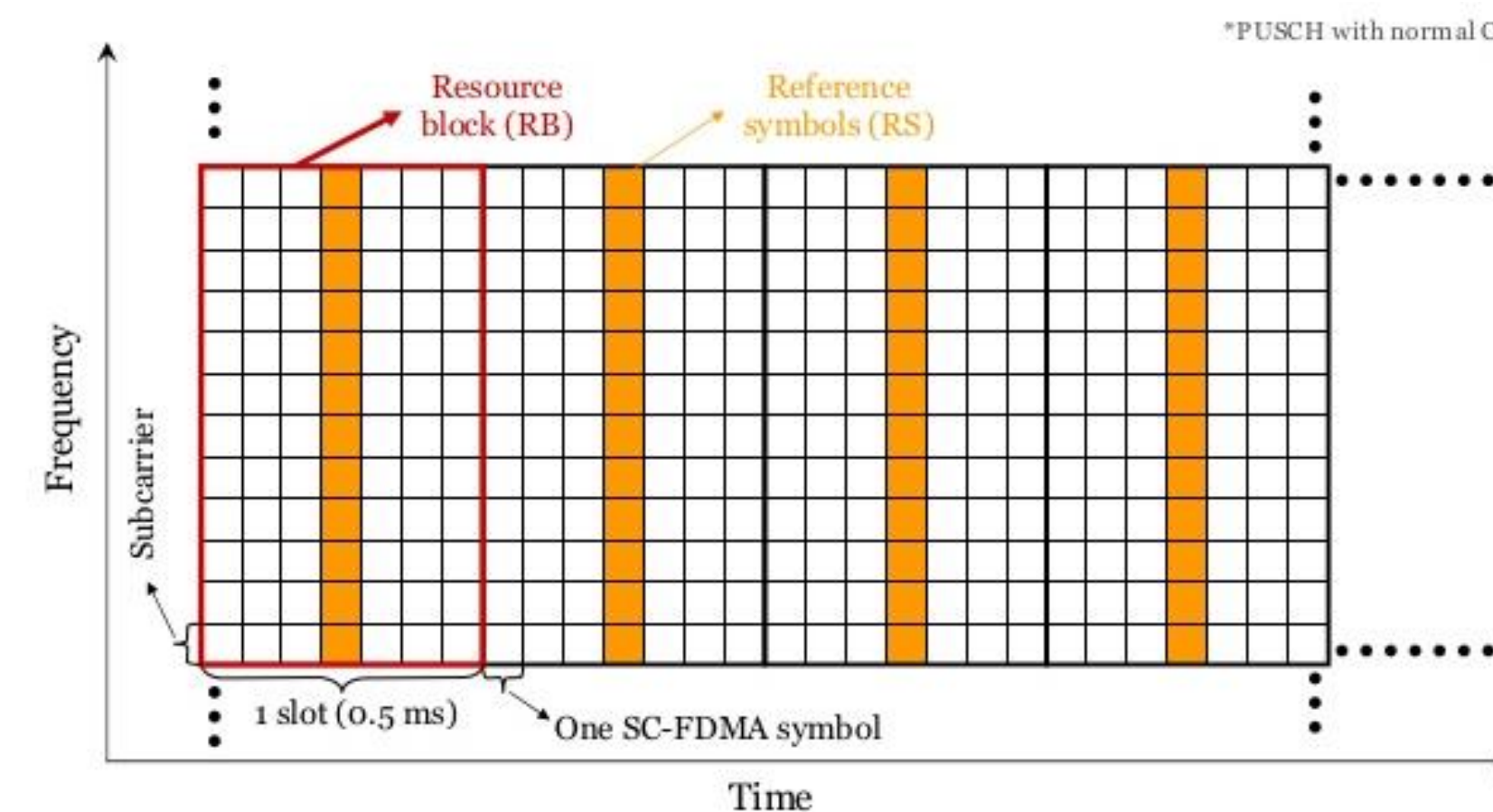
Massive Multiple Access

Fig. 8. Reservation systems cannot scale to networks with thousands of active devices.
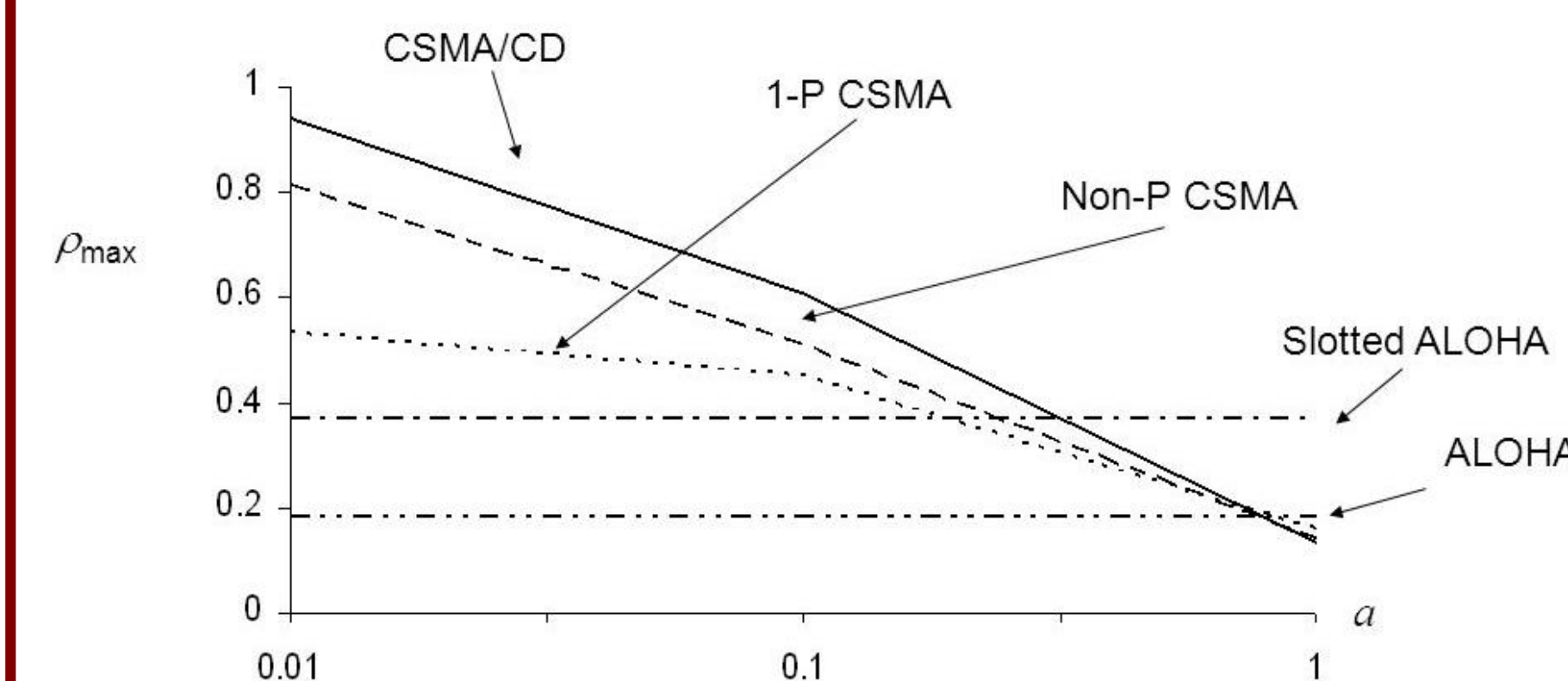

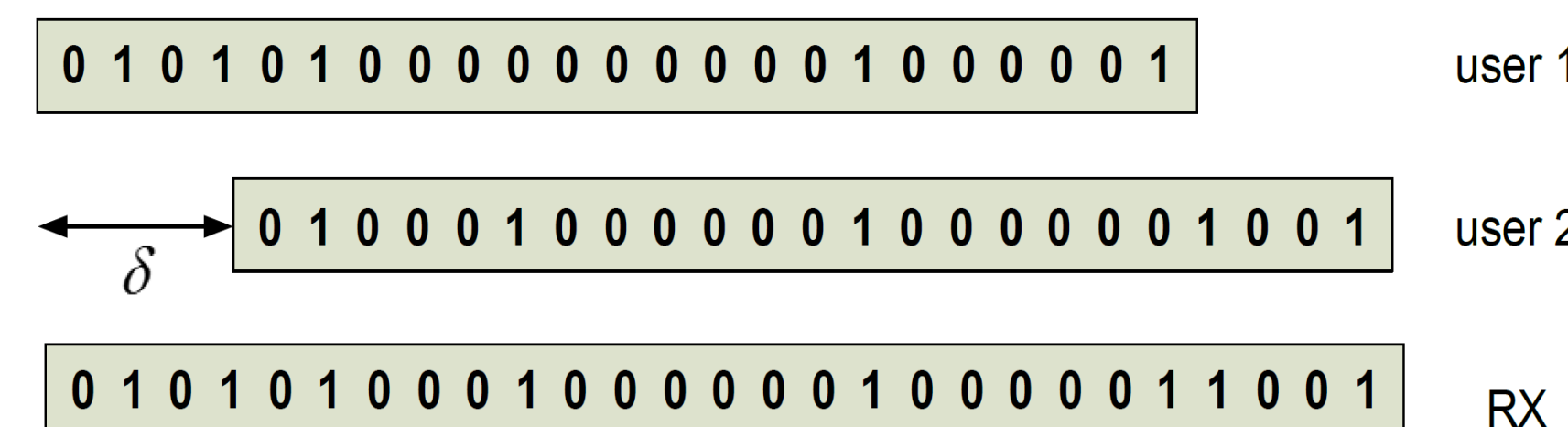Fig. 9. Random access systems are limited by energy and throughput.

Fig. 10 Shift-robust collision resolving codes can apply to IoE nodes.
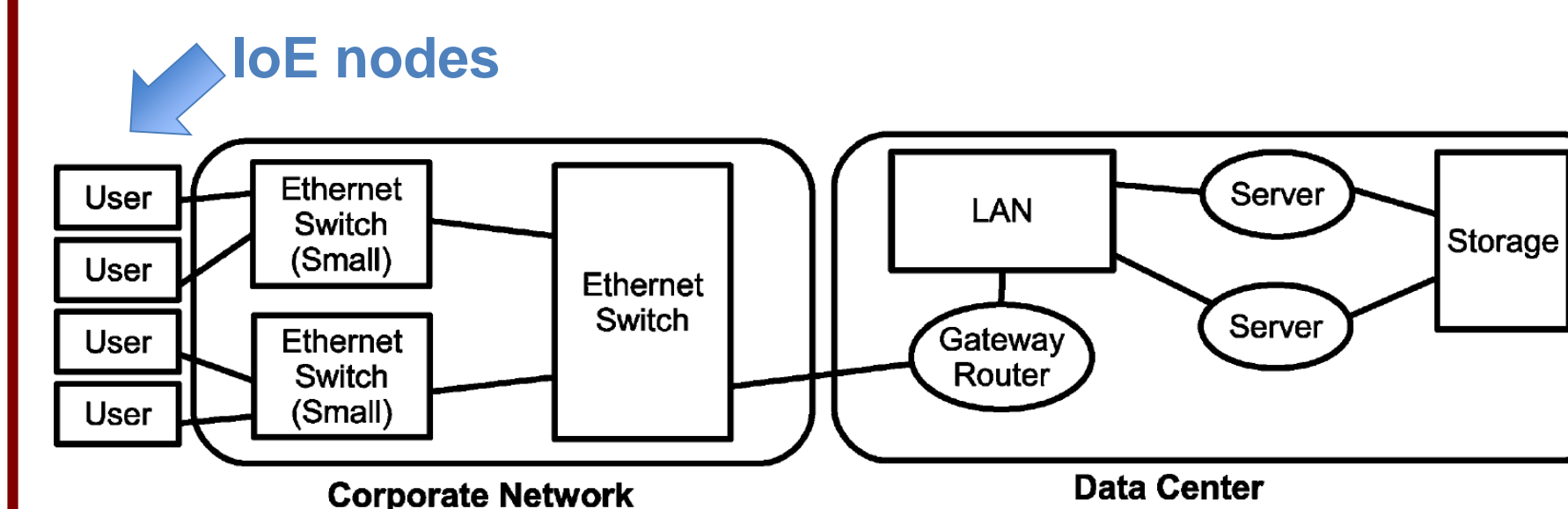
Computation vs Communication

Fig. 11. IoE nodes in the framework of a larger connected network.

- Distributed intelligence → energy savings, improved privacy, higher communication range

- Local computations using clever analog techniques
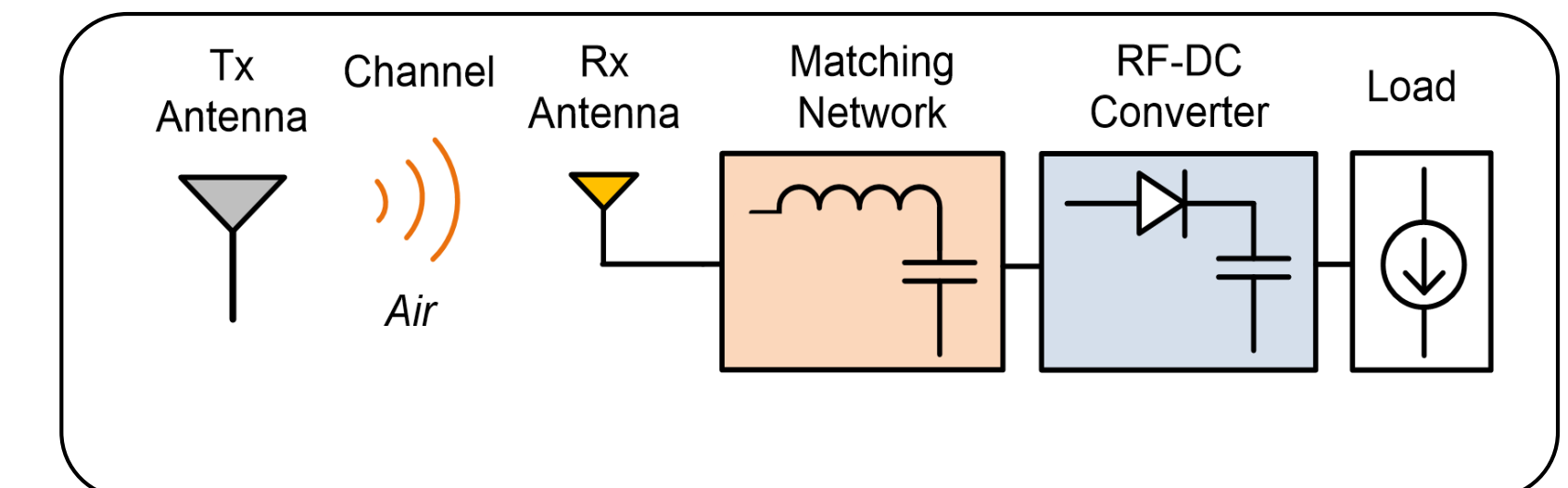
Circuit and System Design

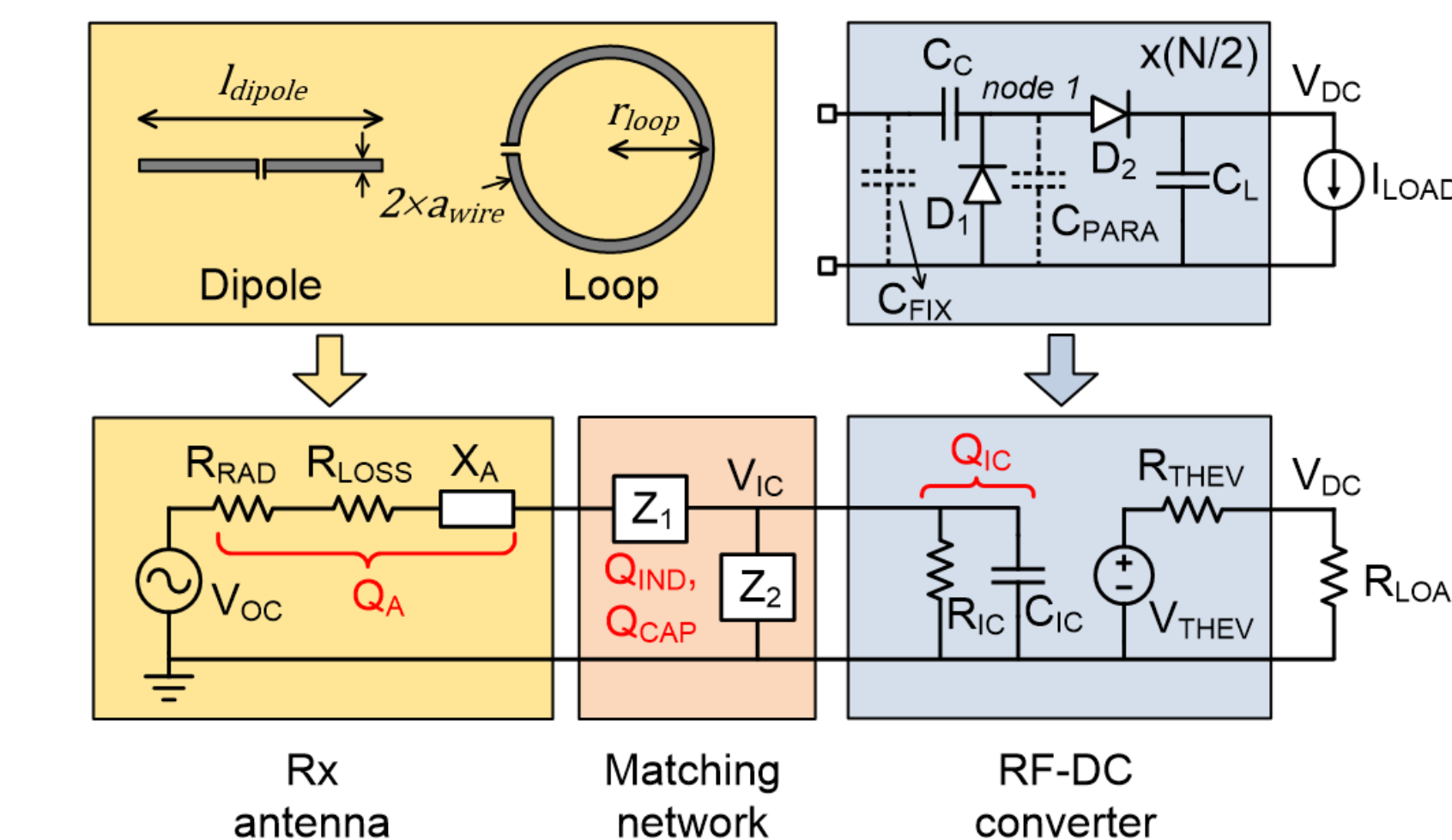Fig. 12. Block diagram of wireless power transfer chain [2].

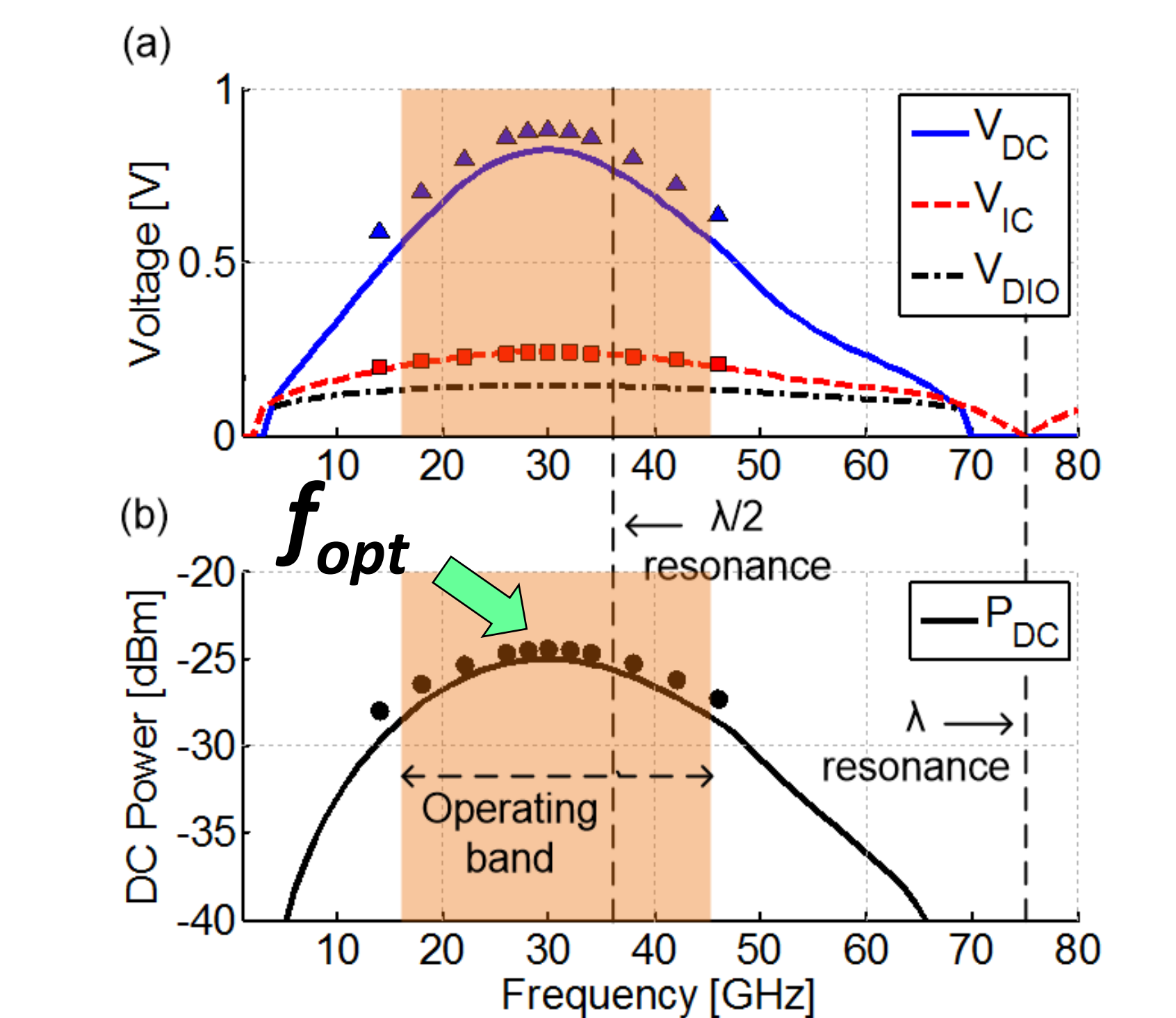Fig. 13. Components of the receiver and equivalent circuit diagram.

Fig. 14. Maximum DC power and voltage vs frequency; optimal powering frequency lies in mm-wave regime.

References

[1] http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/vni-hyperconnectivity-wp.html.

[2] J. Charthad *et al.*, "System-Level Analysis of Far-Field Radio Frequency Power Delivery for mm-Sized Sensor Nodes," in *IEEE TCAS-I: Reg. Pap.*, vol. 63, no. 2, pp. 300-311, Feb. 2016.

[3] http://www.digikey.ca/en/articles/techzone/2011/aug/comparing-low-power-wireless-technologies.

[4] M. Tabesh, N. Dolatsha, A. Arbabian and A. M. Niknejad, "A Power-Harvesting Pad-Less Millimeter-Sized Radio," in IEEE Journal of Solid-State Circuits, vol. 50, no. 4, pp. 962-977, April 2015.