Galvanic Coupled Cyber-Physical Body Sensor Network

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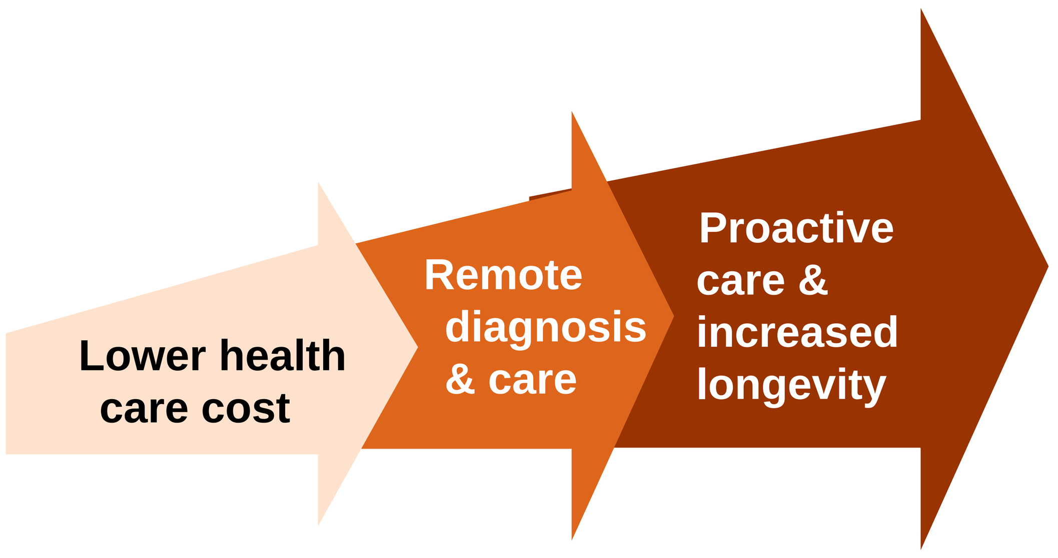
The Promise of Implanted Sensors

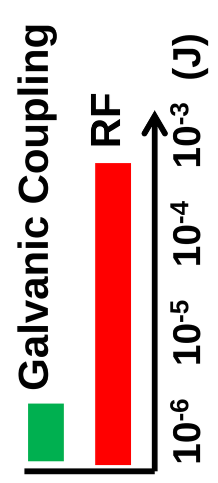
- Future health-care relies on autonomous sensing of physiological signals and controlled drug delivery
- Need for implanted Cyber – Physical Body Sensor Network (CP-BN) that can wirelessly communicate with an external control point



Why Galvanic Coupled CP-BN

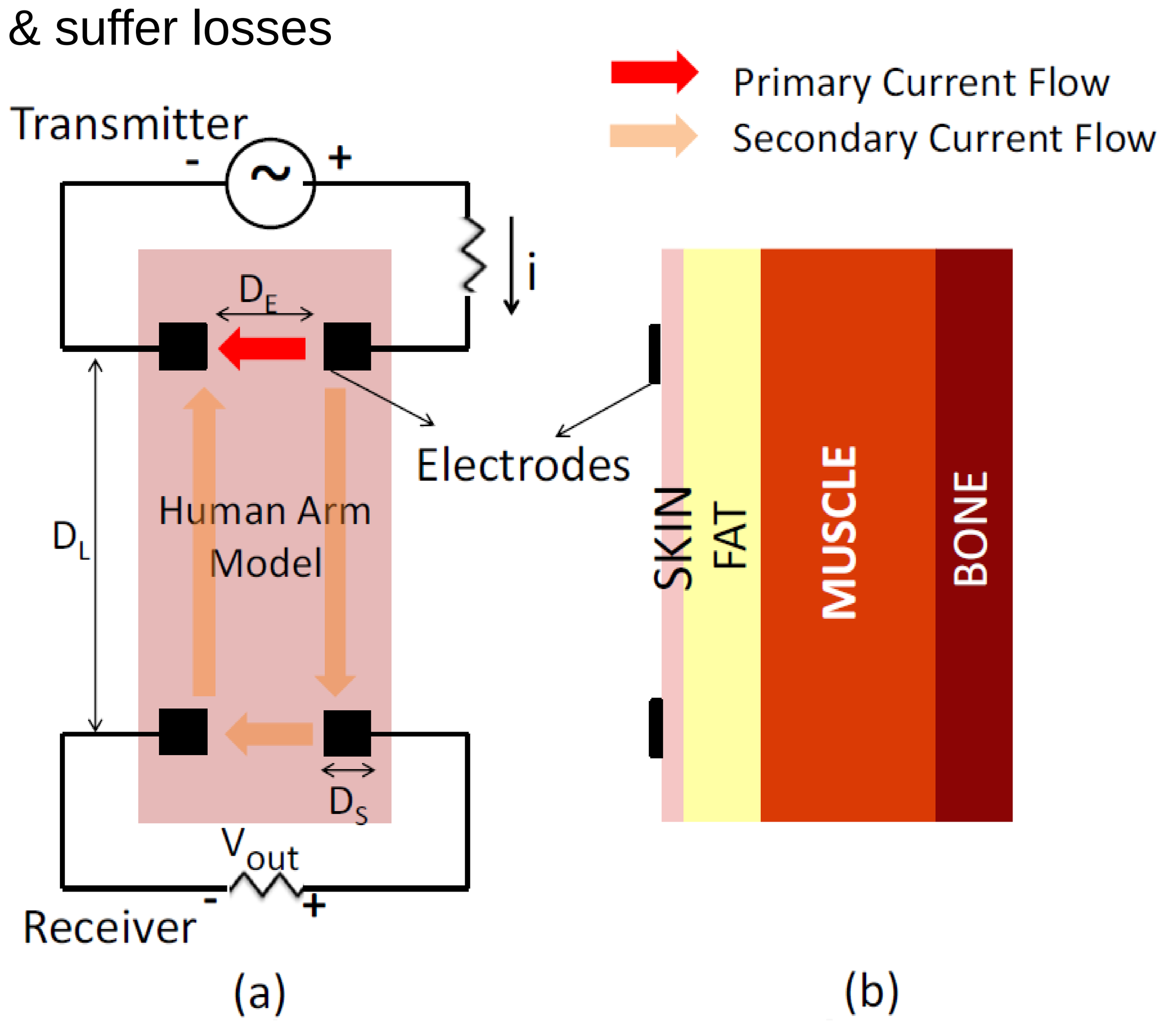
Existing RF based BNs
- not suitable for human tissues containing water
- consume more power
- does not propagate inside body tissues

Galvanic coupled CP-BN
- mimics body's natural signalling (low frequency signals)
- low interference as energy is confined within body
- consumes two orders of magnitude less energy

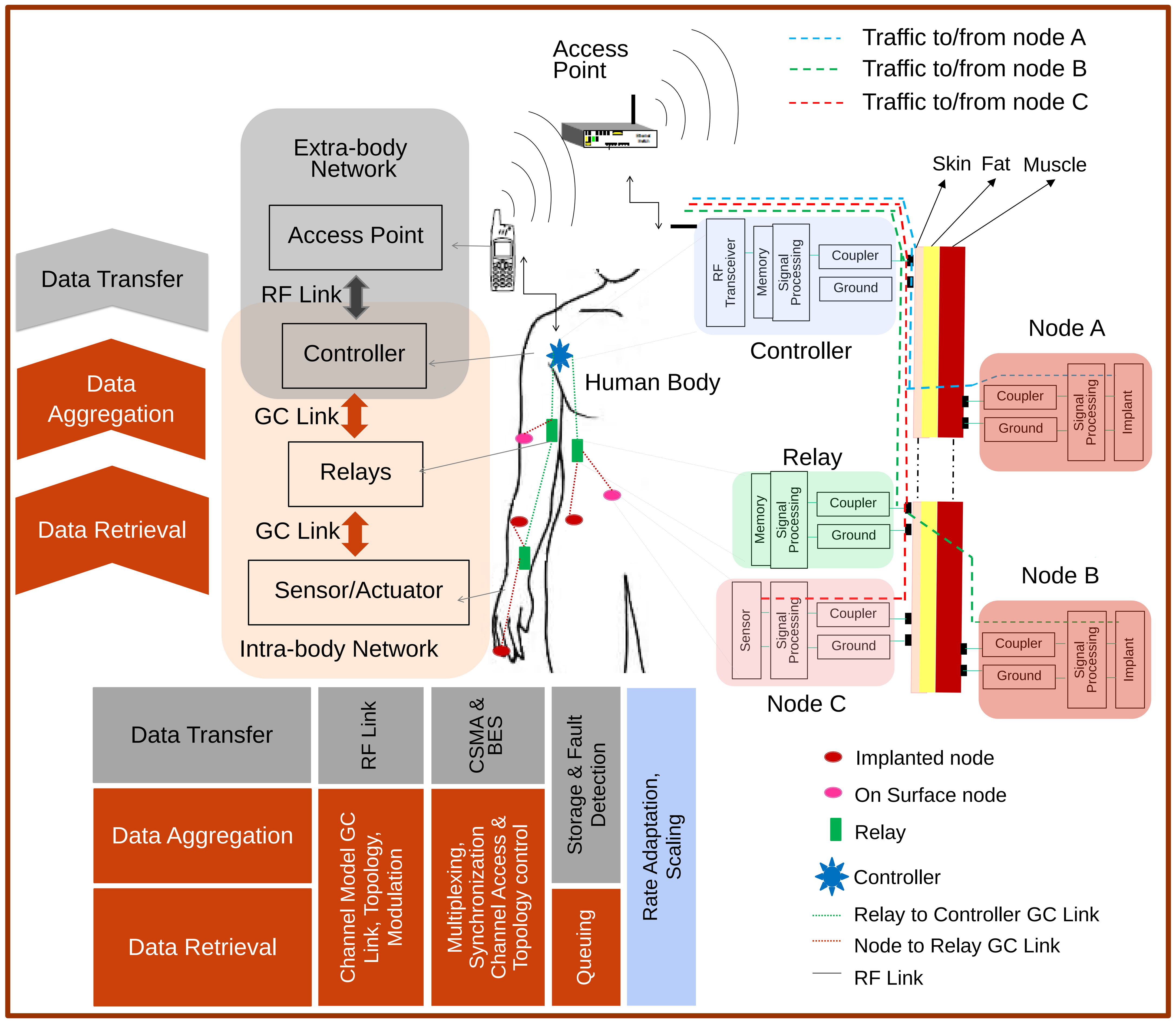


How Galvanic Coupling Works

- Injects low power electrical signal to the tissues
- Weak secondary currents carry data to receiver
- Signal propagates radially across multiple tissues & suffer losses

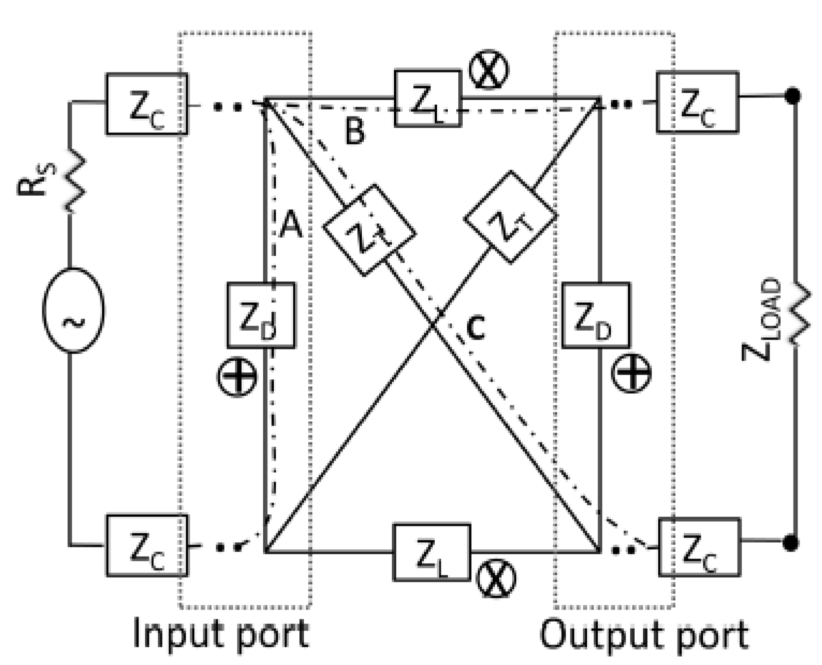


Galvanic Coupling on Skin (a) Front View (b) Cross Section



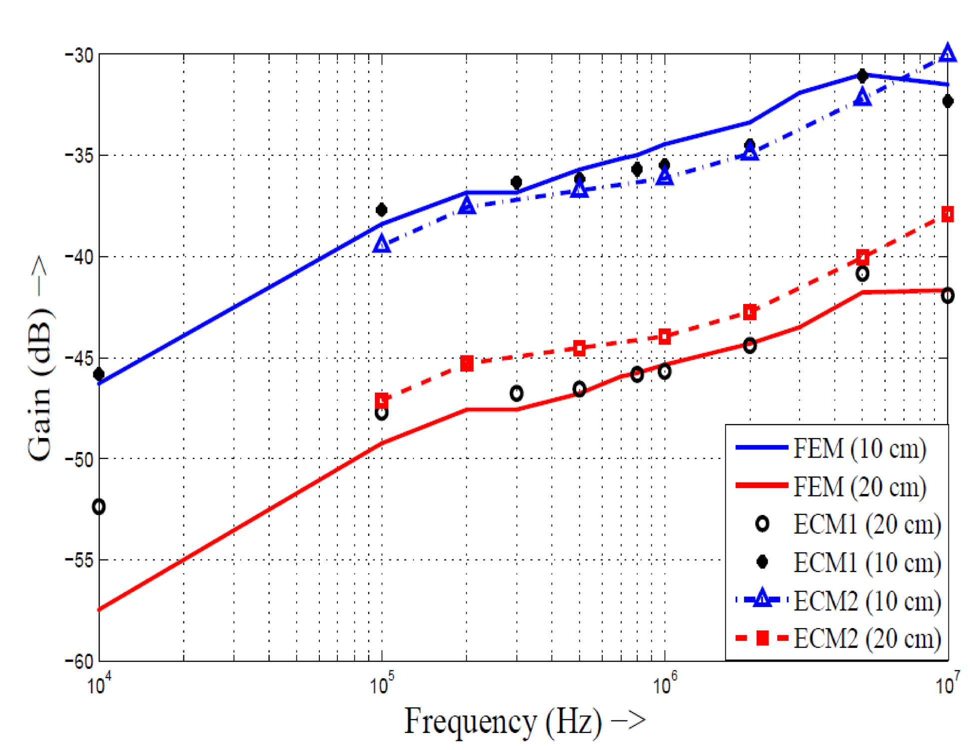
Components and Network Architecture for Galvanic Coupled Cyber Physical Body Network

Signal Propagation Through Human Tissue – Our Models



We constructed a 2-port equivalent circuit model & FEM based ANSYS HFSS simulation suite of human arm using electrical properties of tissues [1].

- obtained an estimate for observed noise and achievable data rates
- identified optimal transmission frequency and electrode placements under varying tissue dimensions
- skin to muscle & intra-muscle links showed lower loss than on-skin links



Channel gain for on skin GC-links

Future Research Challenges

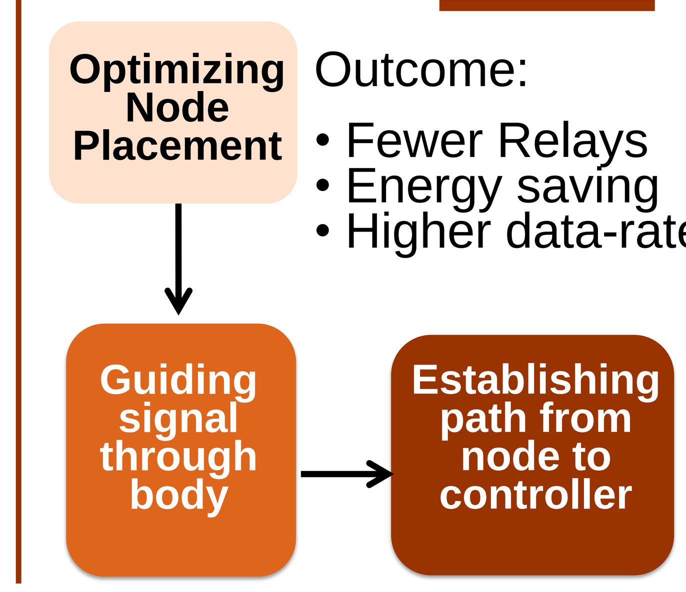
Implementation of Physical Layer

Objective: Establishing reliable & energy efficient CP-BN physical layer

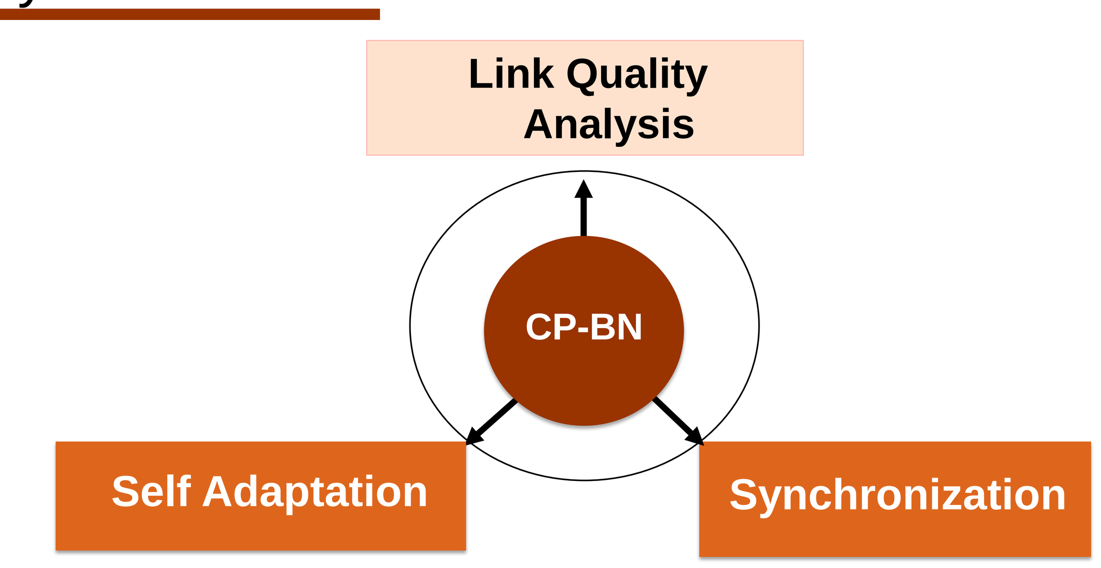
Channel Capacity

- Building transmitter and receiver circuits with suitable modulation schemes that maximizes transfer rate
- Studying the impact of realistic noise figures on capacity

Topology



Physical Protocol



Protocol Design at Network Layer

- The spatio-temporal distribution should be analyzed and leveraged for multiple channel access Eg. TDMA
- The network should distinguish critical situations from normal deviations based on correlations derived from routine activities Eg. High heart rate from heavy activity vs emergency

CP-BN Test-bed

CP-BN operation and performance needs to be Evaluated by building test-beds using
- Human phantoms
- Animal experiments
- Clinical trials

Acknowledgement

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References

[1] ICNIRP (International Commission on Non-Ionizing Radiation Protection). 1998. Guidelines for limiting exposure to time-varying electric, magnetic, & electromagnetic fields (up to 300 GHz).

[2] M Swaminathan, FS Cabrera, G Schirner, and K R Chowdhury, Characterization and Signal Propagation Studies for Wireless Galvanic Coupled Body Sensors, IEEE Journal on Selected Areas in Communications, under review.

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