Fundamentals of Multihop Wireless Networks

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Network Model

- V: a set of nodes
- $c(u,v)$: minimum transmission power of u at which the signal transmitted by u can be received by v successfully when no other nodes than u transmit at the same time.
- $P \in \mathbb{R}_{+}^{V}$: maximum transmission powers of V.
- (Maximal) Communication topology $D = (V, A)$:

$$(u,v) \in A \Longleftrightarrow c(u,v) \leq P(u).$$

Roadmap

- **Minium Power Requirement by A Link**
- Communication Topology
- Power Control
- Interference Models
- Primitive Communication Tasks

Path Loss Model

When a node u transmits a signal at power p, the power of this signal captured by another node v is

$$\frac{\eta(u,v)\,p}{\|uv\|^{\kappa}},$$

where

- $\|uv\|$: Euclidean distance between u and v,
- κ: path loss exponent (a constant between 2 and 5)
- $\eta(u,v)$: reference loss factor of the pair (u,v).

Signal to Noise Ratio (SINR)

- ξ: ambient–both internal and external–noise power
- The *SINR* at v is

$$\frac{\frac{\eta(u,v)p}{\|uv\|^{\kappa}}}{\xi} = \frac{\eta(u,v)\,p}{\xi\,\|uv\|^{\kappa}}.$$

Minium Power Requirement by A Link

σ: threshold of SINR for successful reception
Since

$$\frac{\eta(u,v)\,p}{\xi\,\|uv\|^{\kappa}} \geq \sigma \Longleftrightarrow p \geq \frac{\xi\sigma}{\eta(u,v)}\,\|uv\|^{\kappa}$$

we have

$$c(u,v) = \frac{\xi\sigma}{\eta(u,v)}\,\|uv\|^{\kappa}.$$

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Communication Topology

$P \in \mathbb{R}_+^V$: maximum transmission powers of V.
Communication topology $D = (V, A)$:

$$(u, v) \in A \Longleftrightarrow c(u, v) \leq P(u).$$

Maximum Transmission Radius

- Assumption: all pairs have equal reference loss factor η.
- Symmetric power requirements:

$$c(u,v) = c(v,u) = \frac{\xi\sigma}{\eta}\|uv\|^{\kappa} \propto \|uv\|^{\kappa}.$$

- *Maximum transmission radius* of u:

$$R(u) = \left(\frac{\eta}{\xi\sigma}P(u)\right)^{1/\kappa} \propto P(u)^{1/\kappa}.$$

- Simple construction of D:

$$(u,v) \in A \Longleftrightarrow \|uv\| \leq R(u).$$

Transmission Radius

- Further assumption: all nodes have equal maximum transmission power P
- Equal maximum transmission radii $R = \left(\frac{\eta}{\xi\sigma}P\right)^{1/\kappa}$.
- If all nodes in V lie in a plane, $\overline{D}$ is a R-disk graph.

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Communication Topology Produced by A Power Assignment

- Power assignment: $p \in \mathbb{R}_{+}^{V}$ with $p \leq P$.
- Communication topology produced by p: $D_p = (V, A_p)$ where

$$(u, v) \in A_p \Longleftrightarrow c(u, v) \leq p(u).$$

Power Assignment Induced by A Subgraph

- $D' = (V', A') \subseteq D$ induces a power assignment $p_{D'}$: $\forall u \in V$,

$$p_{D'}(u) = \begin{cases} \max_{a \in \delta_{D'}^{out}} c(a) & \text{if } u \in V'; \\ 0 & \text{otherwise.} \end{cases}$$

- Power of D':

$$p(D') = \sum_{u \in V'} p_{D'}(u).$$

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Signal to Interference And Noise Ratio (SINR)

Given

- U: a set of nodes transmitting simultaneously
- $p \in \mathbb{R}_+^U$: the transmission powers of U
- $v \notin U$: intends to receive signal transmitted by $u \in U$

The *SINR* at v is

$$\frac{\frac{\eta(u,v)p(u)}{\|uv\|^\kappa}}{\xi + \sum_{w \in U \setminus \{u\}} \frac{\eta(w,v)p(w)}{\|wv\|^\kappa}}.$$

Physical Interference Model

Given

- U: a set of nodes transmitting simultaneously
- $p \in \mathbb{R}_{+}^{U}$: the transmission powers of U

A node $v \in V \setminus U$ can successfully receive the signal transmitted by a node $u \in U$ if and only if the SINR at v is at least σ.

Protocol Interference Model

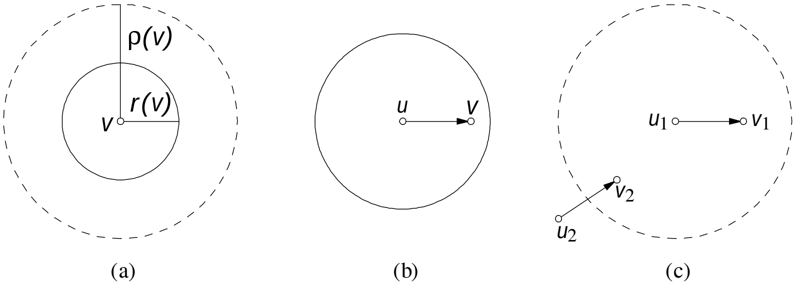

Figure: (a) Communication range and interference range of each node; (b) a communication link; (c) a conflicting pair of communication links.

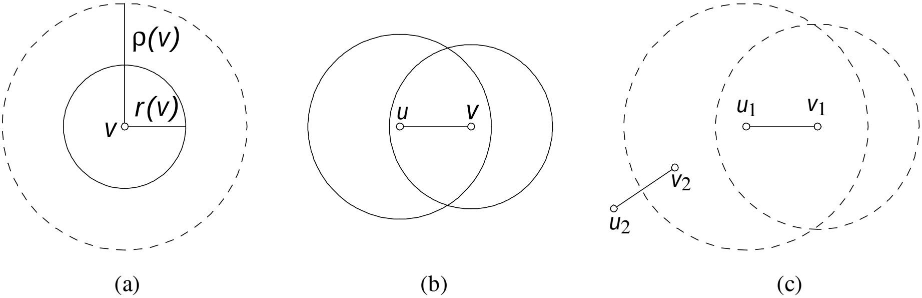

Figure: (a) Communication range and interference range of each node; (b) a communication edge; (c) a conflicting pair of communication edges.

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Primitive Communication Tasks

- Unicast
- Broadcast
- Multicast
- Data gathering
- Data aggregation
- Gossiping
- Beaconing