Post-Optimal Radio: Viral Radio Networks

David P. Reed
Adjunct Professor, MIT Media Lab
dpreed@reed.com
Presented at Viral Communications WG Meeting
MIT Communications Futures Program
January 26, 2005
The Sky is Not The Limit

A simple theoretic argument suggests that the available information capacity of a fixed frequency band is proportional to the number of transceivers in the space.

If you want more capacity, add more radios.
Heuristics

More radio density should be better
Assist with propagation, more degrees of freedom to control
Noise independent of density
Focus on scalable, incremental, adaptive networks
Keep it simple
Don’t seek the optimum
Intelligence at the endpoints
More radios should be better (but are often worse)

If energy needed for distance $r$ grows as $r^d$, then energy needed using $n$ relay hops is $<1/n^{d-1}$ of direct link.

As a result, the impact of a relayed message is much less, allowing concurrent sharing for independent messages.
The limits to theory

Most research on scalable wireless networks has been theoretical

Freespace propagation

Link-based concepts: “Range”, “interference”, “fading”

Practice needs to inform theory, and vice versa.

Optima are brittle
Two paths are better than one

“Zero latency relaying” during symbol
Relies on software defined DSP-based techniques at Tx and Rx
Superposition can be inverted, giving additional diversity gain, e.g. Rake.
Exploiting propagation

A

B

Diagram showing the relationship between nodes A and B.
Opportunistic Relay

Willing, idle nodes offer to relay
Create BitTorrent-like incentives
Picking the “best” relay

Effectiveness depends on channel quality: source-relays, relays-dest, source-dest
Willing relays measure RTS/CTS
Relay “offers” time-delayed by f(channel)
First relay to respond wins, defines Tx params
Observations & questions

Idle nodes act as sensors
Propagation variability *helps*
Voluntary cooperation -> gain
BitTorrent-like incentives (help me, or I won’t help you next time)
Can it scale?
What range of demand can it serve?
Extensions being explored

Wideband signals

frequency-dependent fading is a feature, not a bug

Relay subbands “independently”

Exploit cheap software radio, such as GNU USRP

Support multicast traffic (Li)

Network “fairy dust”
Spectrum Policy

Favor radio networks that cooperate, interoperate, and adapt - OpenSpectrum

How can spectrum be both scarce and empty?
Why shouldn’t the bulk of wireless connectivity be infrastructure-free, cooperative, and incremental? Like automobiles, not subways?
If wireless networks can support exponential improvement for the next 25 years, shouldn’t regulators step out of the way?
The missing bureau

FCC recognizes radio:
   Broadcasting
   Point-to-point communications
   Networks

Why doesn’t it have a Bureau of Radio Internetworks