

Interference Avoidance, Infostations and Economics

Christopher Rose

Associate Director, WINLAB

the Wireless Information Networks Laboratory

at Rutgers University

Dept of Electrical and Computer Engineering

<http://www.winlab.rutgers.edu/~crose>

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WHAT IS WINLAB?

- Academic Research Unit within E&CE
- Strong ties to CS
- 15 Faculty, 40+ Grad students in a trailer
- 5 to 10 year wireless horizon
- Supported by corporate sponsors and Gov't grants
- Recently added Economists to the mix!!

⇒ now looking to influence national spectrum policy

AN INTERESTING OBSERVATION

- Cellular Voice: 10kb/s, \$V/minute
- Cost of 1MB Data: $\approx 13V$
 - 30 minutes of MPEG3 music: 30MB — 390v
 - Syncing a disc: 100MB – 1300v
 - A typical powerpoint presentation: 3MB – 39v
- At 1 or 0.1 cents/minute: carefree use unlikely
- 0.1 cents/minute: voice revenue disappears
- NO difference for 3G wireless because 13v is 13v is 13v.

BOLD CLAIM: Cellular can't carry low (enough) cost data

WIRELESS HARDWARE OF YORE

- Clumsy, Fixed Transceivers
- Expensive Equipment
- Little Wireline Infrastructure

SPECTRUM MANAGEMENT OF YORE

- Central Licensing Authority
- Spectrum Police
- Litigation to protect infrastructure investment

WIRELESS HARDWARE TODAY

- Sophisticated signal processing
- Cheap Transceivers
- Agile Transceivers
- Extensive Wireline Infrastructure

What is spectrum management of tomorrow?

LAY OF THE LAND

- Multiple uses and users
- Unpredictable uses
- Multiple manufacturers and service providers
- Irregular network structures

Standards committees meet at sanitariums

A TYPICAL WIRELESS DREAM

- Develop Hardware – spend money
- Roll Out Infrastructure – spend big money
- Roll Out Service – make (LOTS)² of money (eventually)

OR NIGHTMARE

- Someone else deploys a noise-bomb application
 - Service dies
 - Investment lost

CATCH 22

- Must buy license to preclude noise-bomb
- No idea what license fee is sustainable *a priori*
- Business fails
 - from lack of license
 - from (ignorantly) high bid for license

THE USUAL SCENARIO

- Massive entry costs require deep pockets
- Entry costs preclude many competitors
- Deep pockets require large stable return
 - Carefully assess market
 - Find least common denominator cash cow

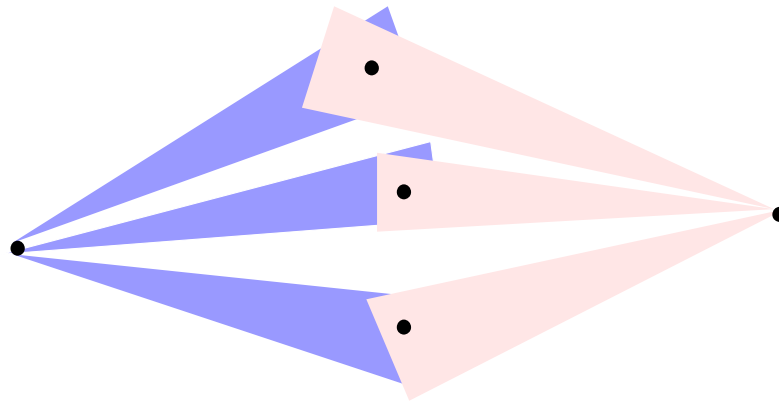
Social Cost: service diversity suffers

TOWARDS A SOLUTION: first, an abstraction

- Spectrum as the “Commons”
- Greediness
- Overuse
- Service Degradation

Make the Commons Bigger!

SOLUTION I: A Bigger Commons

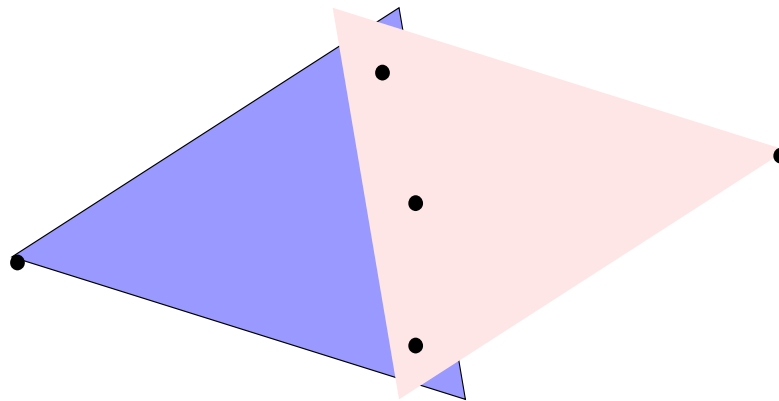


$$\text{Per User Rate} = (M - 1)W \log \left(\frac{P}{(M - 1)WN_0} + 1 \right)$$

Each cow brings grass!

NOTHING IS FOREVER

- Overcrowding Probably Inevitable
 - scattering limitations
 - aperture and directivity limitations



$$\text{Per User Rate} \leq \frac{1}{M} W \log \left(\frac{MP}{N_0 W} + 1 \right)$$

Tragedy of the Commons

WHAT NOW?

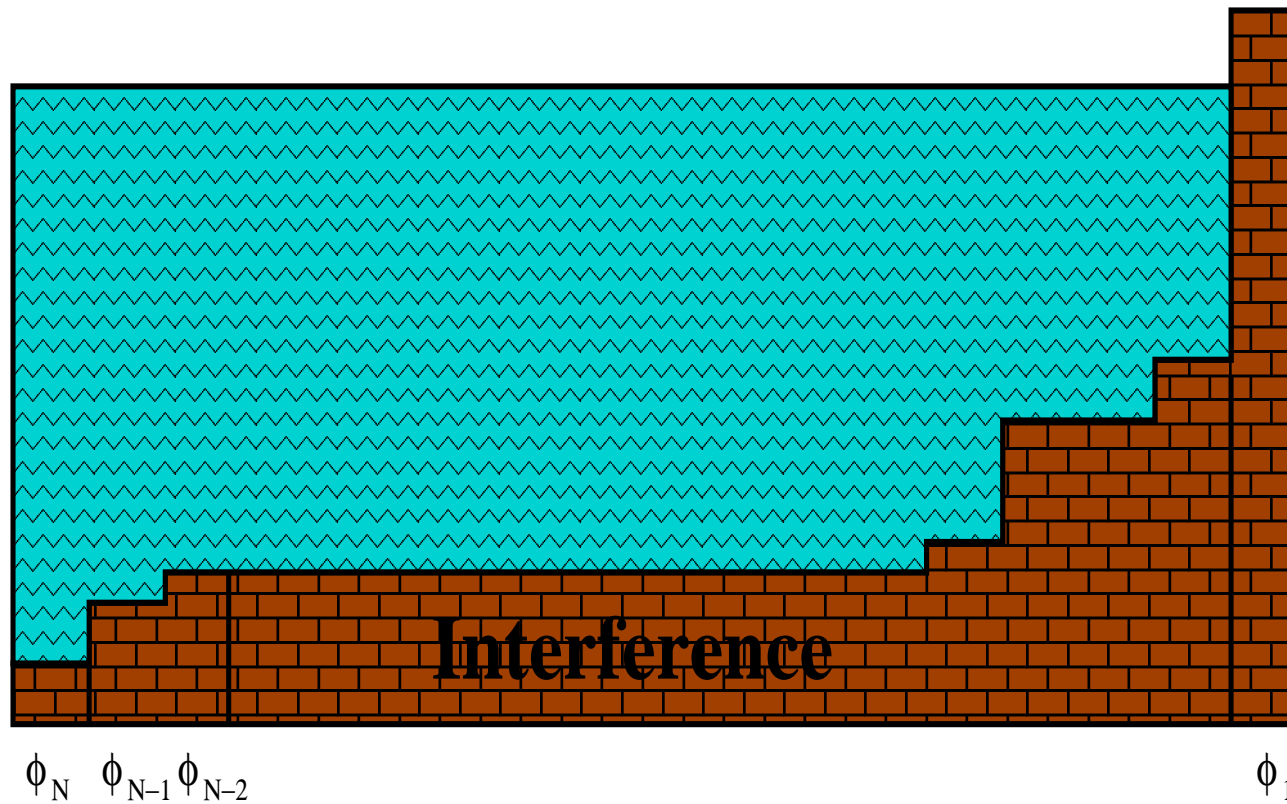
- Some Observations
 - people tend to congregate
 - long range transmissions kill you (interference)
 - long range carriage kills you (multihop)
- Local zones of coverage are natural
 - contiguous cells, (or more likely at first) isolated hotspots
- Congregation points often have landlines

SOLUTION II: Discrete Unlicensed Wireless Zones

ZONAL POLICY: Adam Smith and Darwin

- Define zones via real estate ownership
- **Tie spectrum rights to zone**
- Cobble into network with landlines (*a la* Internet)
- **Let market evolve** transceiver protocols
 - Agile, Self-policing, Interoperable
 - The fittest survive
- Selective **economic** pressures
 - Landowner policing
 - Landowner system choice

AGILITY: Interference Avoidance



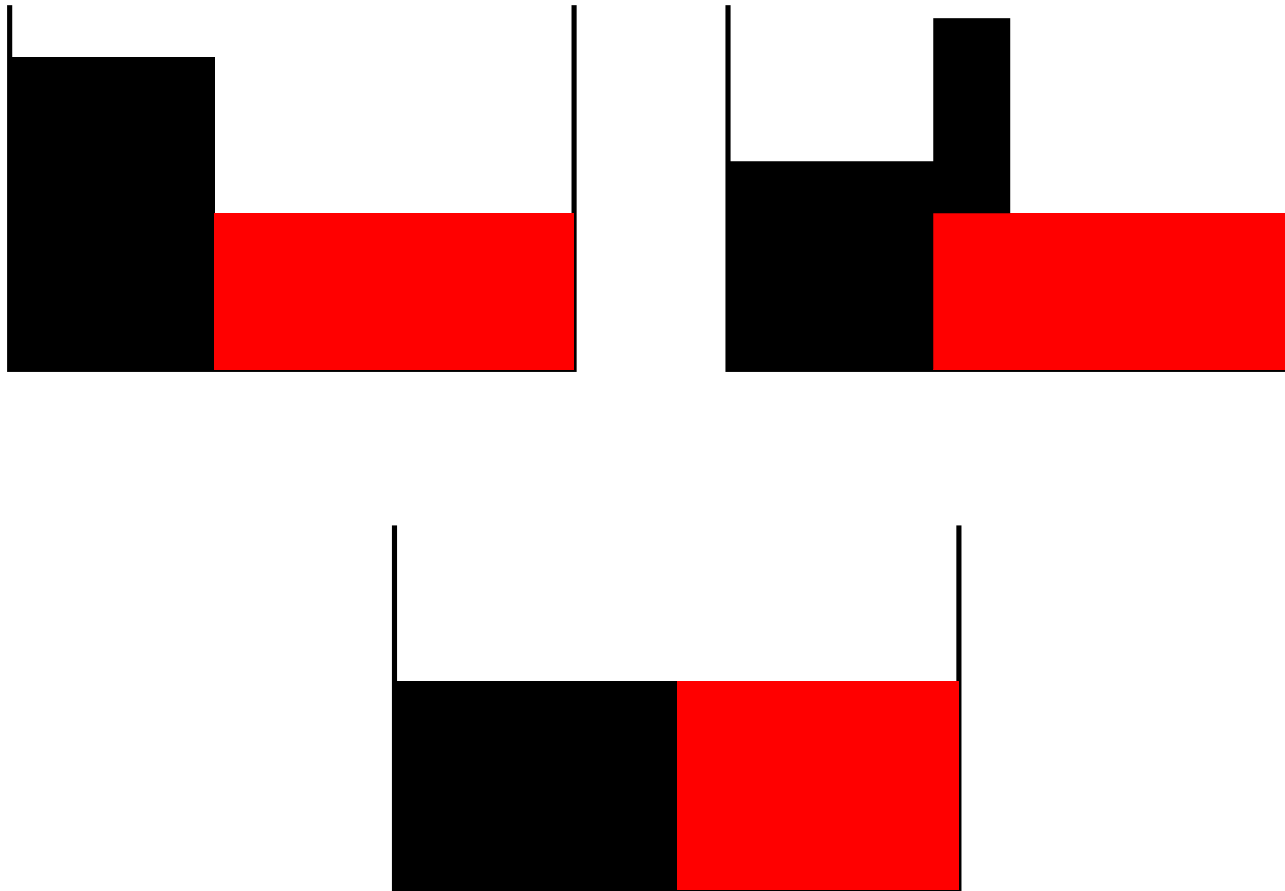
Waterfilling

SELF-POLICING: Spectrum Warfare



Marked for Deletion

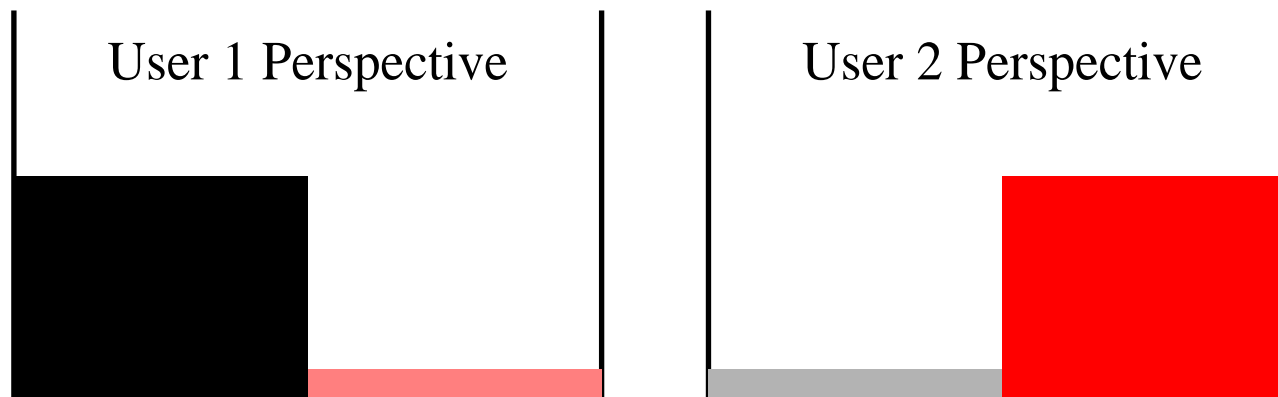
SELF-POLICING: Spectrum Warfare



Self-Interest and Aggression Can Work!

THE FITTEST SURVIVE: Fear of the Zone God

Games of Cooperation and Defection



Average Play Judged by Zone

OTHER DISCRETE ZONE ISSUES

- Growth toward zonal contiguity
 - might need adjudication between "landowners"
 - interference sniffers for provable right/wrongdoing
 - but evolved protocols might be respectful enough
- Cannot let wireline gouge wireless!
 - wireline carriage as commodity
 - multiple competing carriers

CONCLUSIONS

ASSUMING: Agile (software) radios + wireline infrastructure

- Unlicensed Spectrum With Zone “Mineral Rights”
 - Adaptive Transceivers (interference avoidance)
 - Self-Policing (spectrum warfare)
 - Informed Market Choice By Zone (expel bad systems).
- Lowers Entry Barrier
- Encourages Competition

SOCIAL BENEFIT: Market-sustainable service innovation