Analog Programs: Mobile Code for Fibers and Ethers

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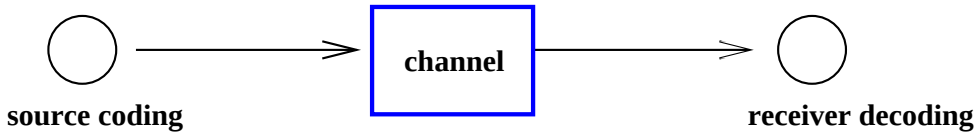
Summary

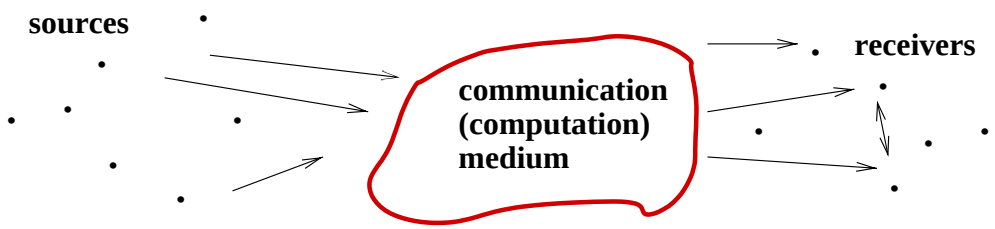
- **Communication media are computation media**
- Wireless: Programmed Interference
- Fibers: Computing Crystals
- Fusing Code and Data
- Automated Program Synthesis

Communication is Computation

Network information theory: Shift . . .
from Shannon's single–src–single–rcv scenario



to multi–src–multi–recv scenario (interference is not noise)



Analog (Communication) Machines

"Programming" = planned use of side effects for solving a task.
Example: flipping logic gates

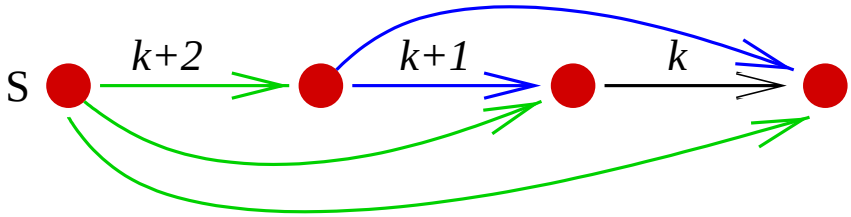
Hypothetical analog **"transponder machine"**:

- NW of wireless frequency transponders:
  – output freq map, power$_{out}$ dependent on input (freq, ampl)
  i.e., analog input steers analog output (ctrl and data)
- Von Neumann: (memory) bus to pass from data to code
  Transponder machine: ether to swap data, ctrl
- *Analog Programs:* frequency pulses, timed forwarding gates, forwarding paths, analog routing, mobile programs

Wireless: Programmed Interference

Coherent multi-stage Relaying with Interference Cancellation (CRIC), Xie and Kumar, DIMACS03 NW inf theory workshop

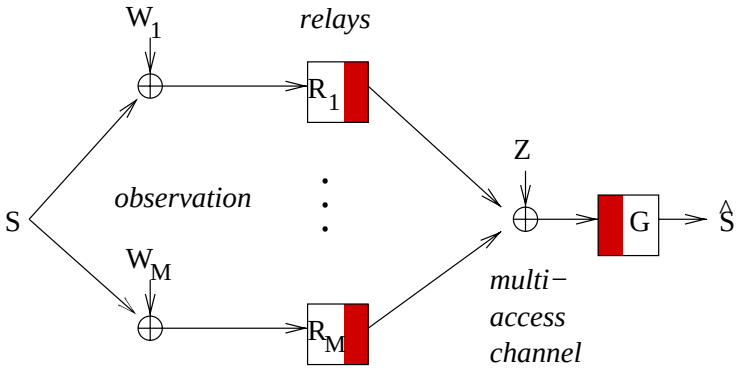
- Upstream nodes cooperate s.t.
  all downstream interferences are canceled



Analog programming II: the ether computes the interference.
Need highlevel "instructions" to express computation strategies.

More reasons to stay analog . . .

Passing from analog into the digital domain considered harmful.



Scenario: M sensors observe an information source and relay their readings over a broadcast channel to the destination.

Result (Gastpar+Vetterli): Distortion function decays as follows:
1/M for uncoded relaying,
1/log M for separation based coding (discretized forwarding)

Fibers: Computing Crystals

All-optical components available:

- Fibers: beam splitters, analog amplification
- How to "process" light packets? → Photonic Crystals: non-linear optics through crystal defects, light interactions
- Results e.g.:
  – lossless bending of light, even 90°,
  – programmable routing of solitons (with solitons),
  – lambda shifts,
  – serial to parallel, parallel lookup (header rewriting)

Computing Crystals II

Optical CPU: holy grail

- Most elements (theoretically) ready
- Memory is difficult:
  – keeping state as traveling wave patterns
  – also: electroptical assists
- Two paths towards “processing”:
  aim at digital domain (done, e.g. SPOC) or analog programs
- Research issues: optical light wave processing primitives,
  TRAveling Program Optical Computer (TRAPOC)

Merging Code and Data

“Photons don’t care wether we label them as code or data.”

Wanted: computational model with only one unit, packet oriented

- My model: **Fraglets** = computation fragments
- Fraglets instead of Code and Data:
  – seamless expression of classical, active protocols
- One-liner: **fraglet = prefix stmt packet with continuation**
  (tagged token dataflow, “code” is also a token)
- Instruction set: strict header field processing,
  constant processing time, no “patter matching”

Automated Synthesis of Mobile Programs

Thinking tool–chain and long term: Forget about . . .

- “Analog Program Design” tools:
  can’t calibrate substrate, really
- Dataflow (to Fraglet tokens) compilers:
  open environment, inherently self-modifying

Instead:
– self-regulation part of “mobile communication programs”
– need **automated searching in program space**
→ cf work on protocol synthesis with genetic algorithms

Selected References

- Xie and Kumar: *Wireless Network Information Theory*, DIMACS’03 NIT WS
- Gastpar and Vetterli: *Source Channel Communication in Sensor Networks*, IPSN 2003, LNCS 2634
- Persall: *Photonics Essentials*, Mac-Graw Hill 2003
- Christodoulides and Eugenieva: *Blocking and Routing Discrete Solitons in Two-Dimensional Networks of Nonlinear Waveguide Array*, Phys Rev Lett 87(23), 2001
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