Modelling radio communication from the perspective of mobile apps

Addressing real-world challenges, building on existing infrastructure

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Real world vs. our models

– need for new kinds of realistic models

Advances in mobile communications

- **Last 10–20 years**
- **Impact: billions of people worldwide**

Advances in mobile communications

- **Impressive engineering feat**
  - mobile broadband, devices, apps…
  - infrastructure: GPS satellites, datacentres…
- **Innovations from numerous research areas**
  - math, physics, electrical engineering, telecommunications, software engineering…

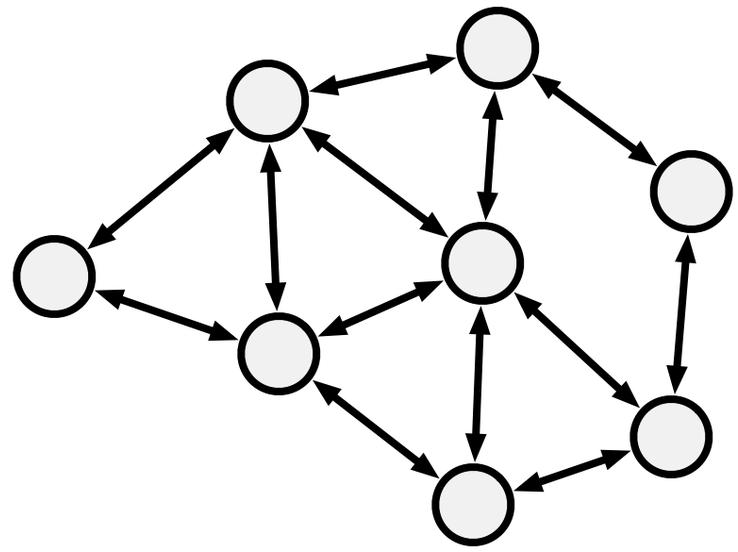
Advances in mobile communications

- **Impressive engineering feat**
  - mobile broadband, devices, apps…
  - infrastructure: GPS satellites, datacentres…
- **Innovations from numerous research areas**
- **Contributions from our community??**

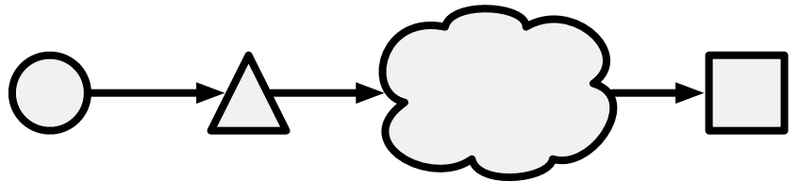
Disparity

- **Models studied in our community**
- **Real-world solutions that actually keep the apps working**

Our models

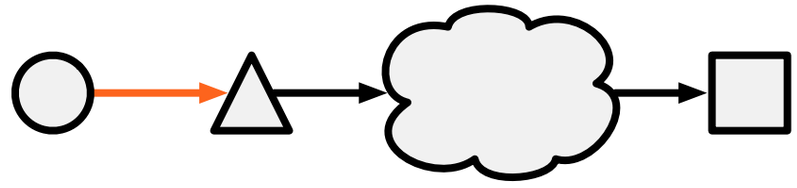


- **Multiple devices in a wireless network**
- **Devices communicate with each other**
- **Algorithm directly interacts with the physical layer**



Real world

- **A mobile app communicates with a server in a datacenter**



Real world

- **A mobile app communicates with a server in a datacenter**
- **Wireless part: point-to-point connection between mobile device and base station**

Real world

- **A mobile app communicates with a server in a datacenter**
- **Wireless part: point-to-point connection between mobile device and base station**
- **Low-level details hidden by TCP/IP stack**

Maybe engineers got it right?

- **Mobile devices actually work pretty well**
- **Standard protocol stack is here to stay**
- **Technology advances, but builds on top of existing infrastructure**

New kinds of “realistic models”

- **Compatible with current infrastructure**
- **Address real-world problems that users & programmers are facing**

Transition

- **From realistic models of physical layer …**

… towards realistic models of application layer

Example

– multiple radios

Very common scenario

- **HTTP GET request**
- **Internet available via 3G and WiFi**
- **Not sure which one happens to work better right now — what to do?**

Similar examples…

- **HTTP POST request**
- **Internet available via 3G and WiFi**
- **Slightly different possible strategies: must not send the same request twice**

Similar examples…

- **Request for coordinates**
- **We could try GPS or WiFi positioning**
- **Neither is guaranteed to work — what to do?**

State of the art?

- **Multipath TCP**
  - requires server support
- **One radio is “primary”**
  - e.g., always prefer WiFi if available

State of the art?

- **Start walking from home to bus stop**
- **Try to check timetables**
- **Mobile phone still thinks it makes sense to use your home WiFi…**
- **Timeouts… waiting…**

Better strategies

1. **Try WiFi first — no answer soon: also try 3G**
2. **Try 3G first — no answer soon: also try WiFi**
3. **Try both WiFi and 3G simultaneously**
    - works fine but expensive

How to model it?

1 = WiFi
2 = 3G

nature:	1	1	1	1	**2**	2	2	2	**1**	2	1	1	1	1	1	1	1	**2**	2	2	**1**	2	1	2
output:	1	1	1	1	**1**	**3**	**3**	2	**2**	**3**	**3**	**3**	1	1	1	1	1	1	**1**	**3**	**3**	**2**	**3**	**3**	**3**
cost:	1	1	1	1	**A**	**a**	**a**	1	**A**	**a**	**a**	**a**	1	1	1	1	1	1	**A**	**a**		**A**	**a**	**a**	**a**

1 = WiFi
2 = 3G
3 = both

wrong radio = large cost A

use both = small cost a

Online algorithms, competitive analysis?

nature:	1	1	1	1	**2**	2	2	2	**1**	2	1	1	1	1	1	1	1	**2**	2	2	**1**	2	1	2
output:	1	1	1	1	**1**	**3**	**3**	2	**2**	**3**	**3**	**3**	1	1	1	1	1	1	**1**	**3**	**3**	**2**	**3**	**3**	**3**
cost:		1	1	1	1	**A**	**a**	**a**	1	**A**	**a**	**a**	**a**	1	1	1	1	1	1	**A**	**a**	**a**	**A**	**a**	**a**	**a**

Compare with what?

Optimal offline solution?

Restricted offline solution?

Example:
Segmentation model

nature:	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**2**	**1**	**2**
offline:	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3**	**3**	**3**	**3**	**3**	**3**	**3**

Intuition: good strategy depends only on environment, and it does not change that often

(e.g., expect changes at most *k* times per day)

Example:
Segmentation model

nature:	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**1**	**2**	**1**	**2**
offline:	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3**	**3**	**3**	**3**	**3**	**3**	**3**

Compare with an offline solution that only changes strategy *k* times per day

(in this example: $k = 3$)

How to solve it?

- **Techniques from online machine learning**
- “prediction with expert advice”
- experts e.g.: “**always 1**”, “**always 2**”, “**always 3**”, “**first 1 and then 2**” …
- almost as good performance as the best expert (“small regret”)

What did we achieve?

- **A fairly clean model**
  - few parameters, easy to state
- **Amenable to theoretical algorithmic work**
  - online algorithms, competitive analysis
  - related work: segmentation problems

What did we achieve?

- **Strange kind of model for wireless networks?**
  - there is very little network here!
  - should we be worried about this?
  - an extreme form of “locality”?

What did we achieve?

- **Addresses real-world problems with wireless communication**
  - mobile broadband is good but not yet perfect
  - could we make millions of users happier?

What did we achieve?

- **Algorithms could be implemented, tested, taken in real-world use**
  - implement in individual apps, few changes in infrastructure
  - implement in system libraries, no changes in individual apps

What did we achieve?

- **Potential for collaboration with other communities**
  - machine-learning approach
  - exploit sensors, learn to predict

Take-home messages

- **Engineers often know what they are doing**
- **Design models that are compatible with existing infrastructure**
- **It is possible!**
  Low-hanging fruits are waiting for you!