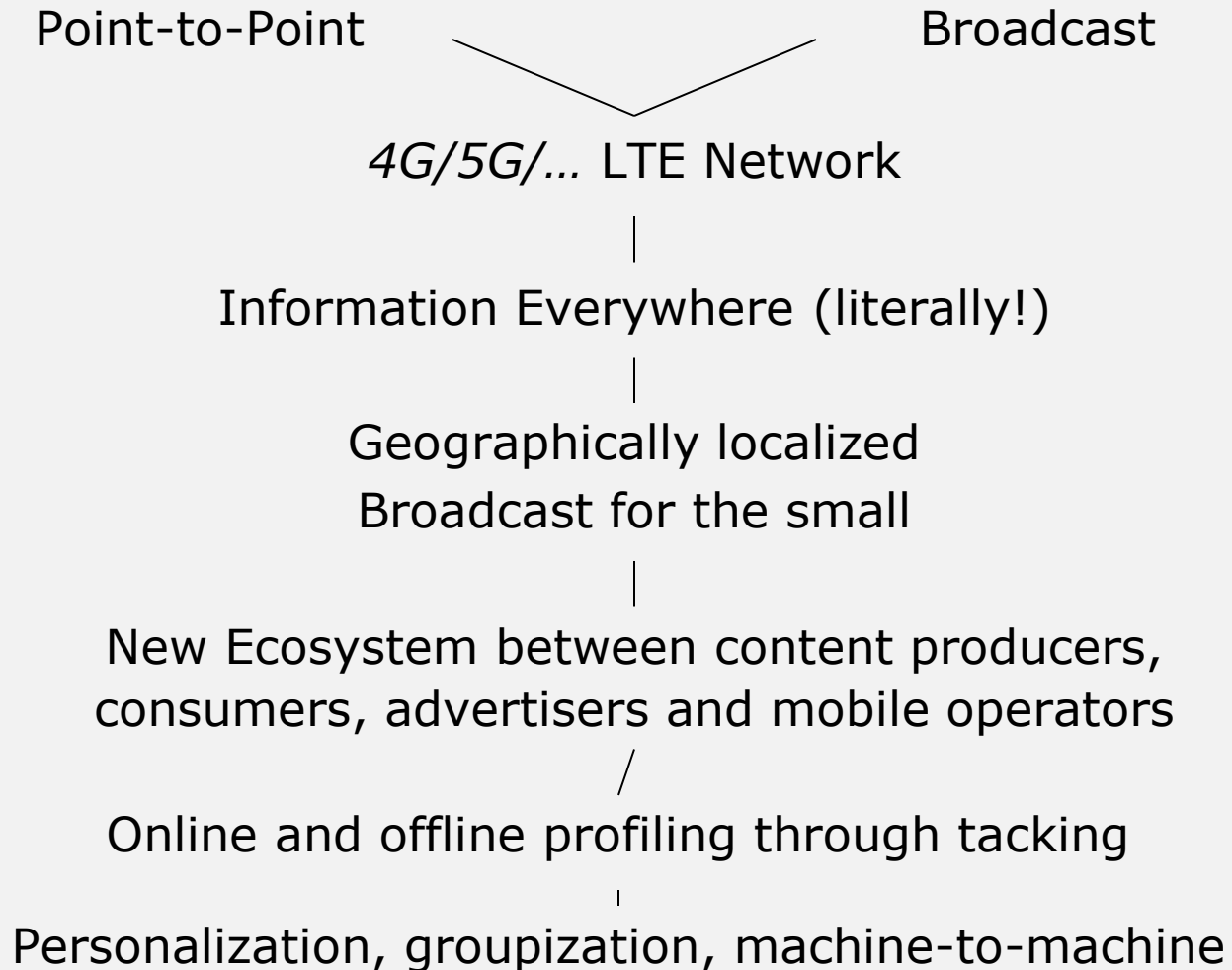


Mobile Data Management: From Man-to-Man to Machine-to- Machine Systems



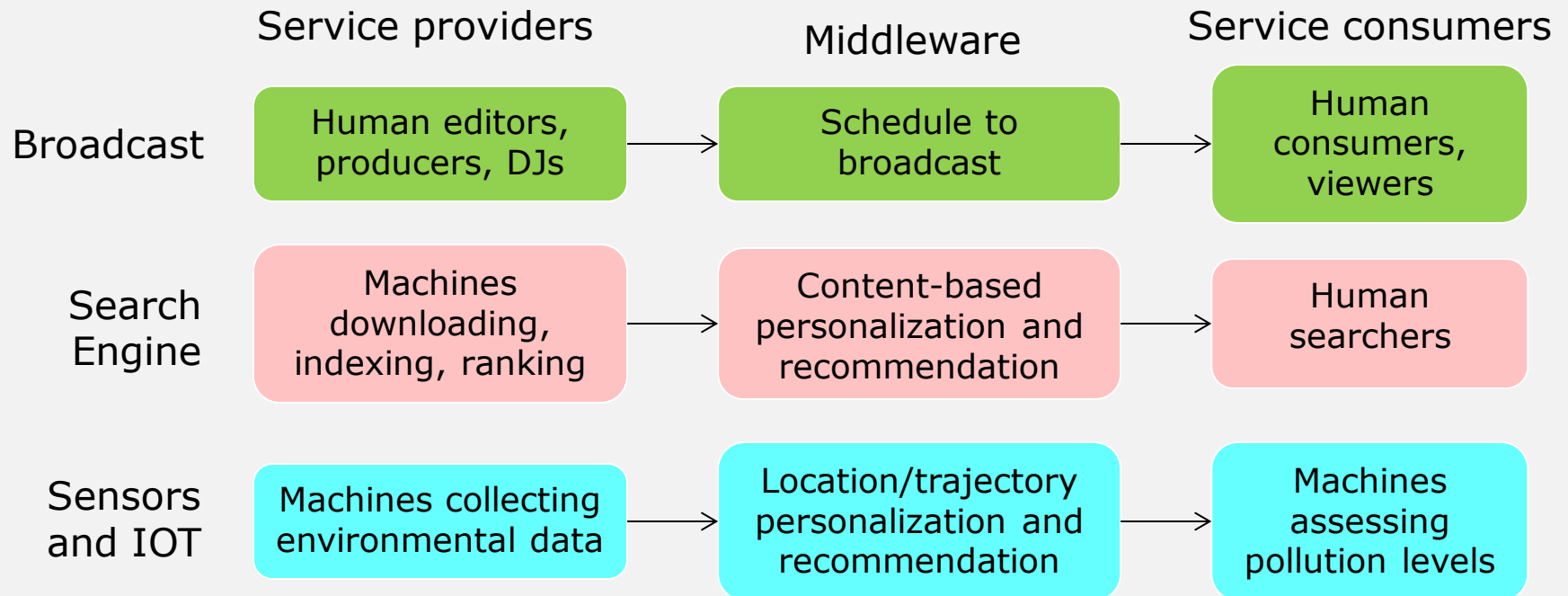
Dik Lun Lee
Department of Computer Science and Engineering
Hong Kong University of Science and Technology
July 17, 2014

The Sales Pitch

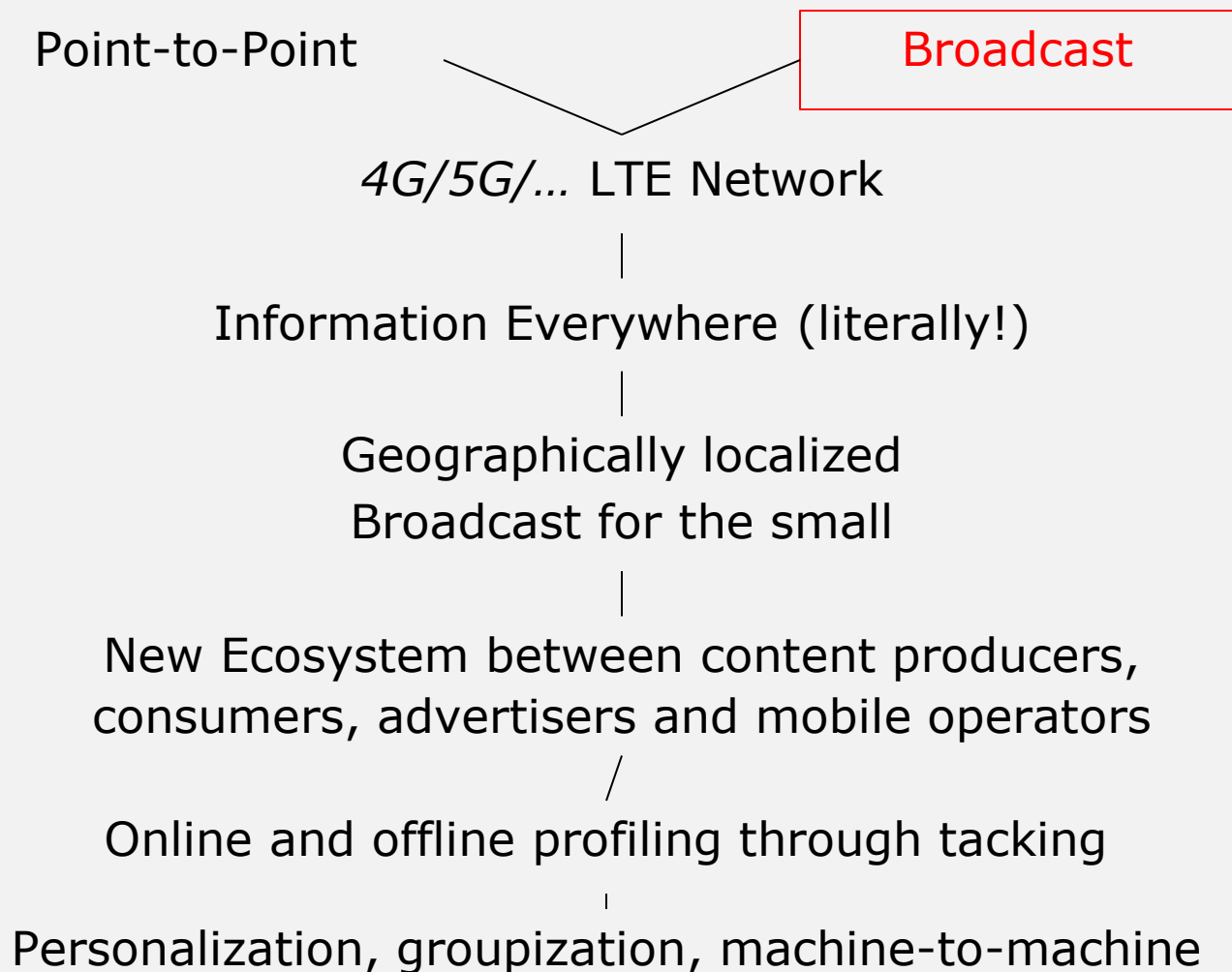


Person-to-Person to Machine-to-Machine

- Person-to-Person: Human involved in both ends of the value chain
- Machine-to-Machine: Machine as information producers and consumers at **both ends** of the value chain

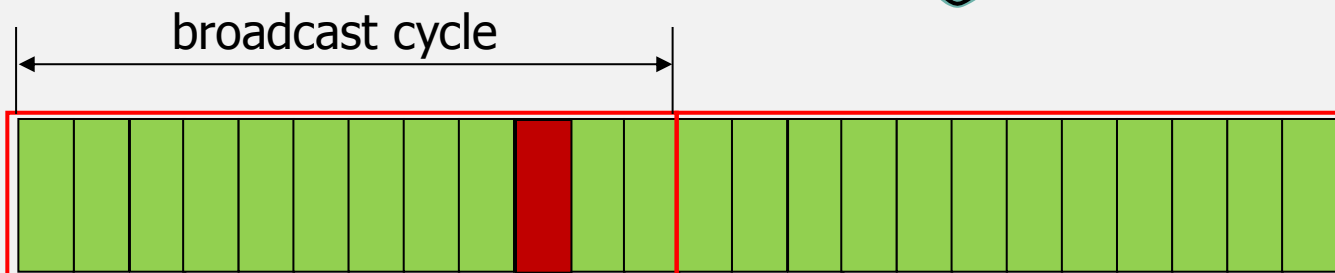
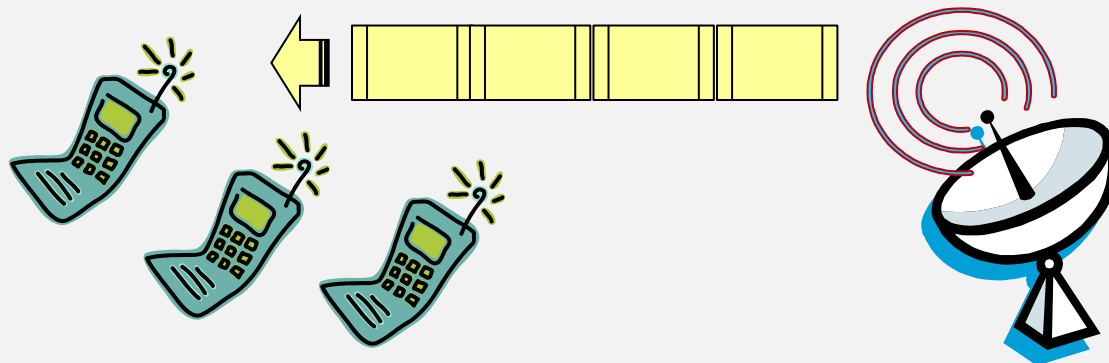


Outline



What is Broadcast?

- Think of it as traditional TV or radio broadcast

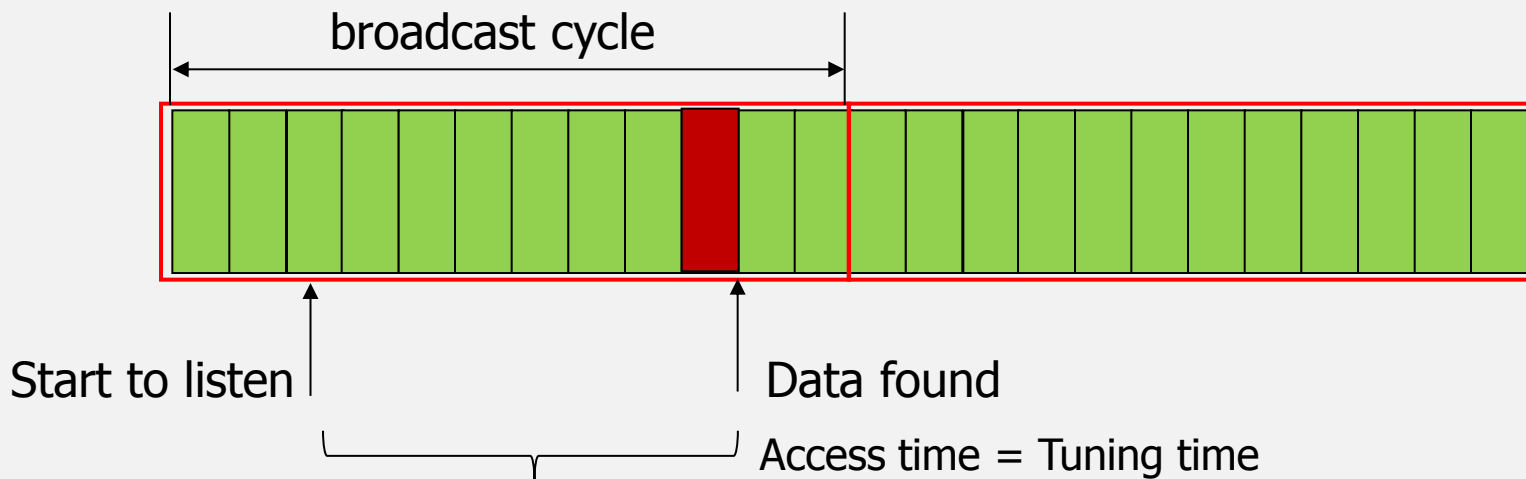


Symbol	Closing Price	Today High	Today Low	Volume	52-week High	52-week Low
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A broadcast item: Structured data; text, video and voice segments, etc.

Performance Measures

- Data channel is like playing a tape over air
 - Scan the tape until you find what you want



- Two concerns:
 - **Access time:** How long do you have to wait
 - **Tune-in time:** How much do you have to scan the data
 - High tune-in time => High battery consumption

Major Research Objectives

- To reduce access and tune-in as much as possible
 - Or to reduce tune-in time without increasing access time
- Other objectives: Data confidentiality, real-time requirement, data dependency, etc.

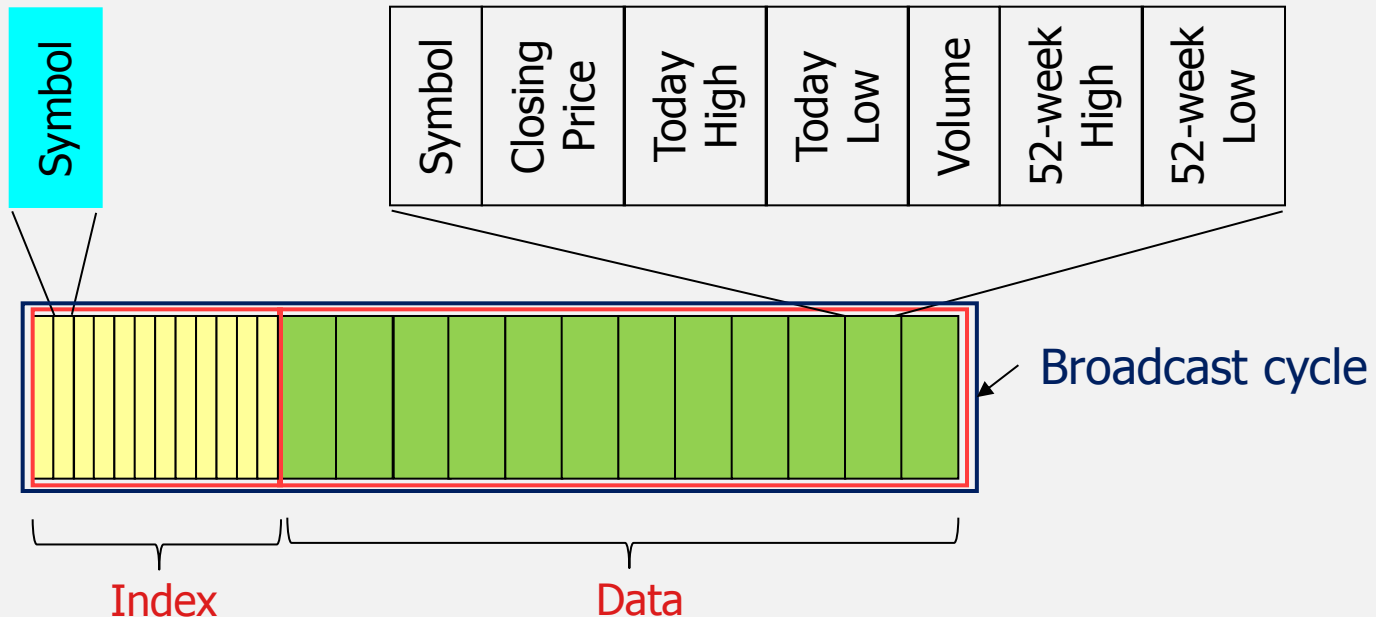
Reducing Access and Tune-in Time

- **Scheduling techniques:** How to schedule data items in the broadcast to reduce access time without increasing tune-in time?
- Two major questions:
 - Which items should come first?
 - How many replicas?
- **Assuming** access frequencies to data items are known
 - Replicate popular items more often: Broadcast disk, etc.
- Scheduling on multiple homogeneous channels
 - Schedule data on channels and then optimize with channels
- Scheduling on heterogeneous channels, ...

Reducing Access and Tune-in Time (2)

□ Indexing techniques:

- An index is like an EPG, which tells when a data item will appear in the broadcast



- Longer access time but shorter tune-in time

Traditional vs Broadcast Indexes

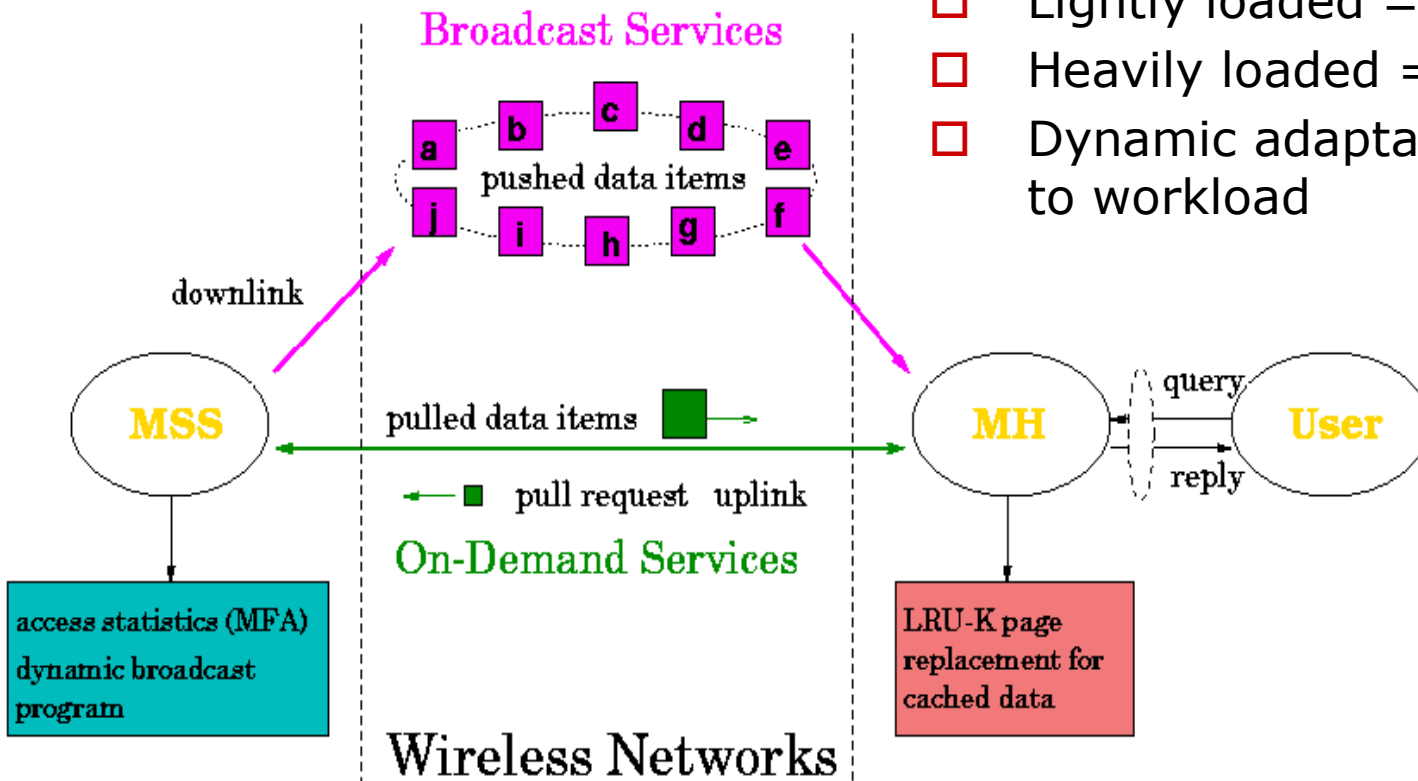
- Differences between traditional and broadcast indexes
 - The sequential nature of the broadcast channel requires new index designs
 - Single level vs multilevel indexes
 - Tree vs signature indexes
 - Interleaving vs non-interleaving indexes

Traditional Index	Broadcast Index
Map a data value to location	Map a data value to time
Index reduces access time because index search is fast	Index reduces tune-in time by telling when a data item arrives
Index is a random access data structure	Index is sequential an one-way searching

On-Demand Broadcast

- ❑ In pure broadcast, clients only listen without transmission
- ❑ On-demand broadcast assumes clients have **uplinks** to send requests to broadcaster
- ❑ Broadcaster then broadcast requested items and clients listen to get what they want
- ❑ Assumptions:
 - There are common requests between clients
 - There are more requests than broadcast slots; need to schedule requests to improve overall performance
- ❑ Example: Pseudo video “on-demand”
 - Subscribers specify the genres of movies; broadcasters allocate movies on different time slots for delivery to subscribers to maximize viewing probability

Hybrid Broadcast



- Lightly loaded => on-demand
- Heavily loaded => broadcast
- Dynamic adaptation according to workload

Potential Applications

- In addition to traditional media broadcast and data services:
 - Offline download and software upgrades, virus signatures, ...
 - Synchronized or coordinated control of client devices
 - Synchronized games
 -

Hurdles of Broadcast

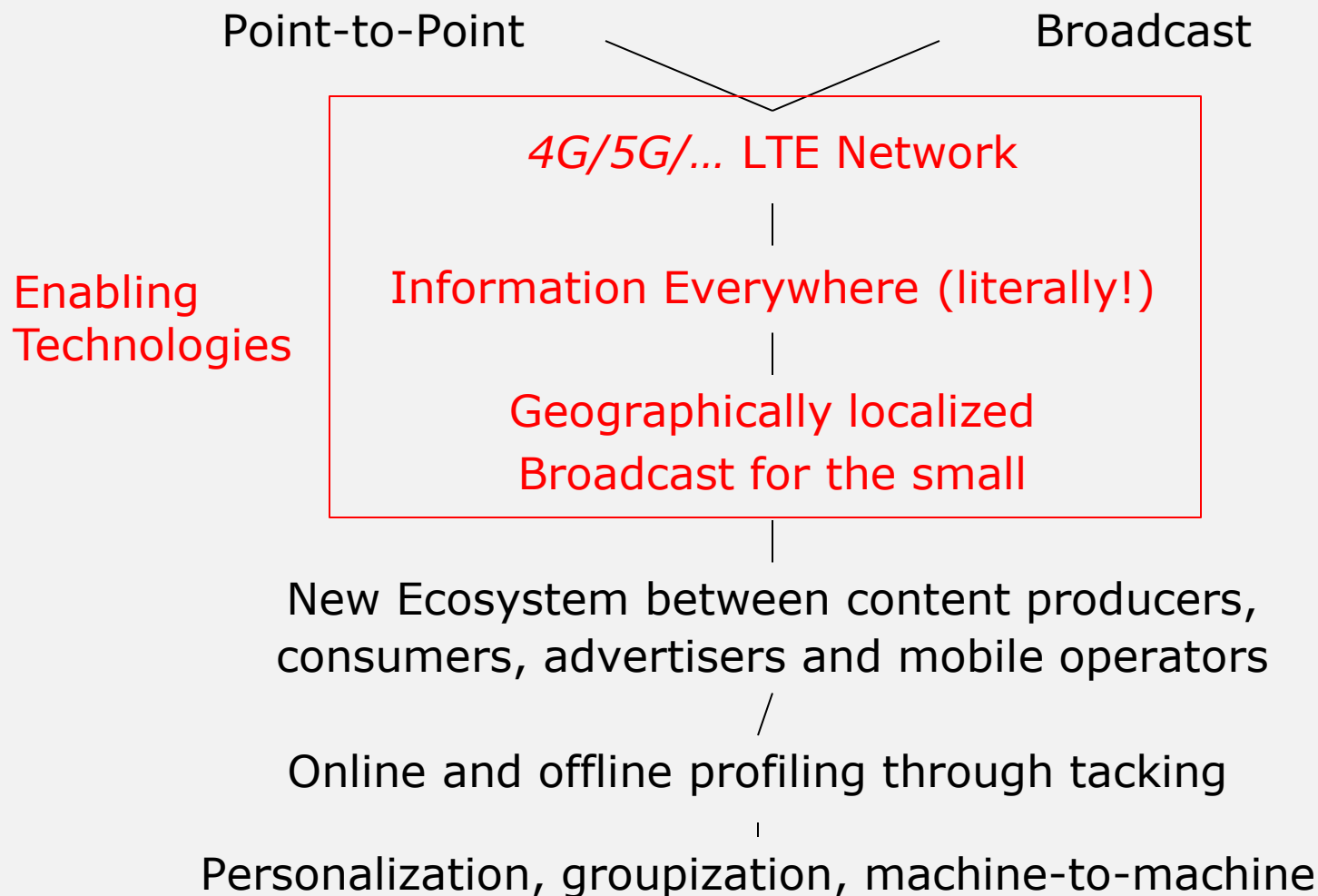
- Cell-based broadcast has been available since 2G, but broadcast has not been widely used, why?

1:1 vs 1:N	Mobile phone networks are primarily for phone calls, which are 1:1, why broadcast?
Now vs scheduled	If I can get what I want right now, why wait for broadcast?
Bandwidth	Bandwidth is cheap; use mobile phone network as internet, which is primarily point-to-point
Openness	Unlike Internet, mobile phone networks have been somewhat a walled garden; it is hard to try out ideas

Stimulators of Broadcast

1:1 vs 1:N	<ul style="list-style-type: none">• Data usage / revenue overtakes voice usage / revenue (soon even if not now)• Resurrection of broadcast encourages new apps
Now vs scheduled	<ul style="list-style-type: none">• Listen anything anytime anywhere• Broadcast is good as a group/family activity• Large live events
Bandwidth	<ul style="list-style-type: none">• Bandwidth is very expensive for network operators• Huge reduction of bandwidth if done right
Openness	<ul style="list-style-type: none">• Mobile clients are more programmable with standard APIs

Outline



Enabler 1: Device Technology

- Availability of smart phones with high quality display and high processing power that lead to new consumer behavior
 - Encourage information consumption on mobile devices; 30% of all video watching were done on mobile devices
 - Consumers are used to ad driven business models

Enabler 2: Broadcast in 4G Networks

- Broadcast is an integral part of a mobile phone network
 - LTE (Long-Term Evolution) is a truly global mobile phone standard
 - LTE Broadcast / Multicast is built on LTE and is supported in 4G mobile phones (e.g., Samsung Galaxy Note 3)
- Live broadcast of large events: sports, conferences, etc.
 - Verizon live-broadcast Super Bowl over LTE broadcast, Feb 2014
 - Viewing of alternative programs alongside main broadcast
 - Saving bandwidth and increasing reliability compared to streaming

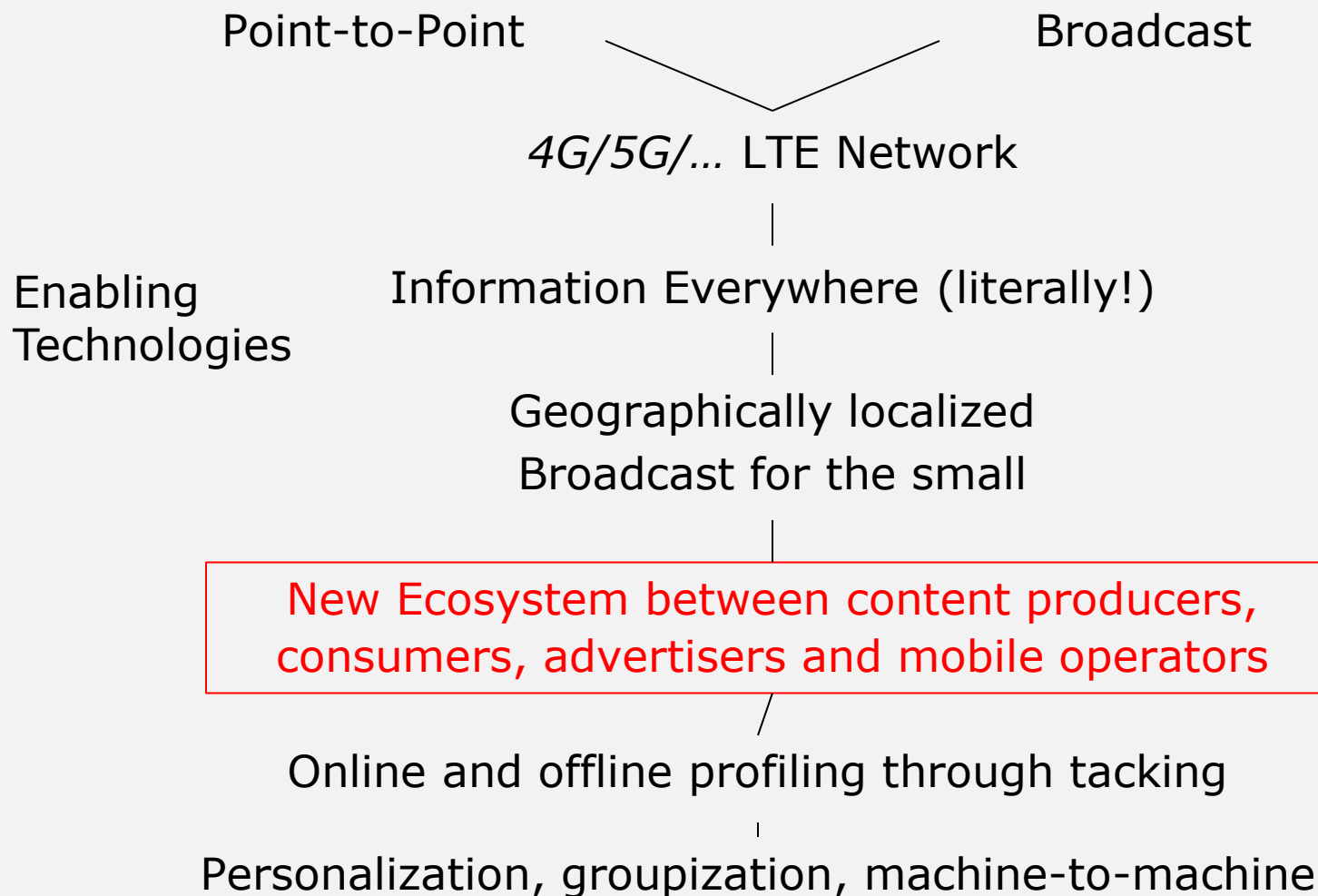


-
- ❑ FIFA expected 3.2 billion people watching World Cup 2014
 - ❑ 50% increase of TV coverage of the matches compared to World Cup 2010
 - ❑ The total number of tweets generated around World Cup 2014 in the first week has exceeded that of the entire World Cup 2010
 - ❑ 32.1 million tweets generated during the Germany – Argentina game; 618,725 tweets/min at 18:37 Brazil time
 - ❑ Facebook: 350m users generated 3b posts, likes, etc., during the tournament, largest social event on Facebook; 88m users and 280m interactions during the final
 - ❑ Real-time social interactions during a live event; people do not just watch passively; they react to it
 - ❑ Broadcast synchronizes the excitement across the globe !!!
<http://mapplinks.com/world-cup-final-twitter-record/>

Enabler 3: Broadcast for the Small

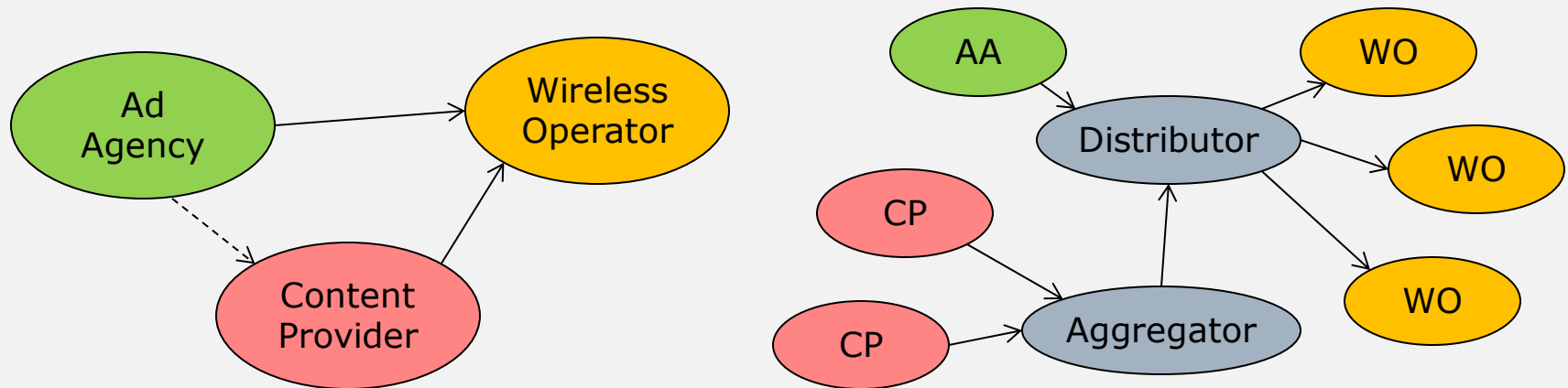
- Cellular networks are inherently location-based
 - Different programs can be broadcast in different cells
 - The same program can be broadcast in multiple cells (single-frequency network)
 - Emergency notification (natural disasters)
- Cells are increasingly small (10-100m) and moving indoor
 - Information can be broadcast pinpointing to a specific area
 - Broadcast for the small: Allowing small content providers to “connect” to small consumer groups via broadcast

Outline

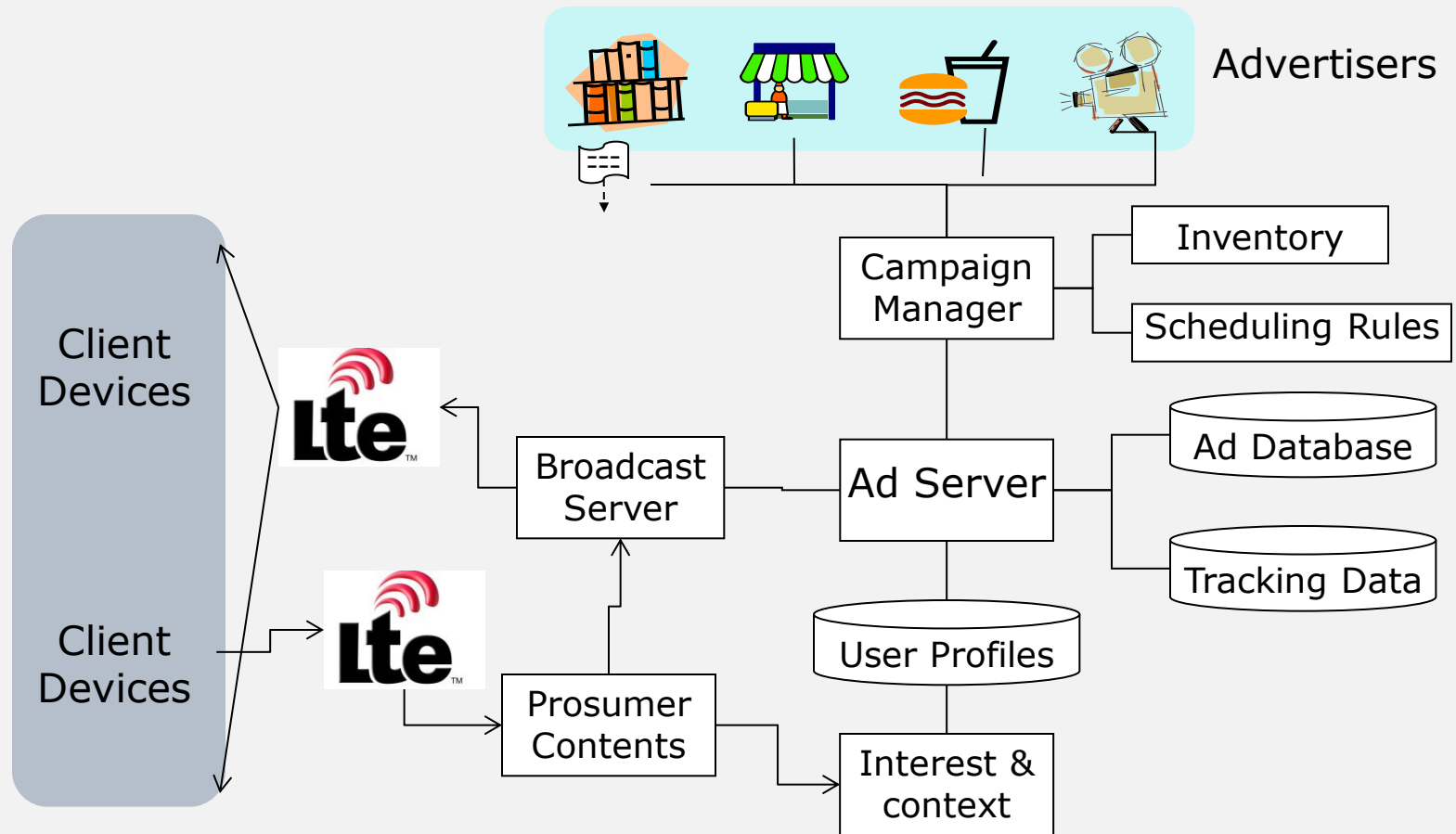


New Ecosystem

- Tried-and-true Internet ecosystem consisting of content providers, advertisers, platform providers and consumers
- Similar ecosystems can be built around broadcast
 - Disaggregation of broadcast infrastructure, information providers and ad agencies
 - Contents and ads can be created by anybody (prosumers) and uploaded for broadcast

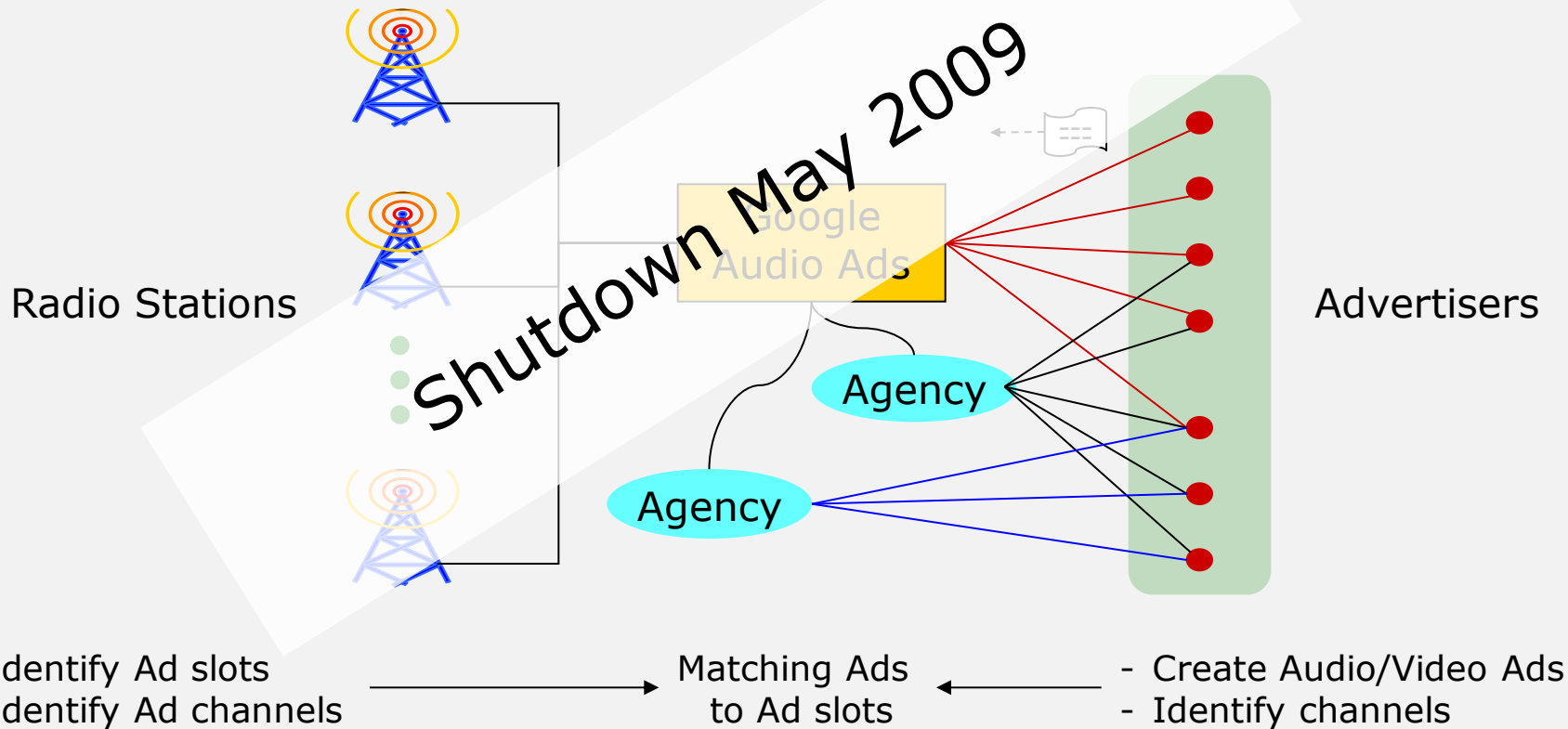


An Example of Ecosystem



“Tried but Failed” Google Audio

- ❑ A commercial example of location-based broadcast
- ❑ An example where publishers (radio stations) and advertisers take control of the broadcast schedule



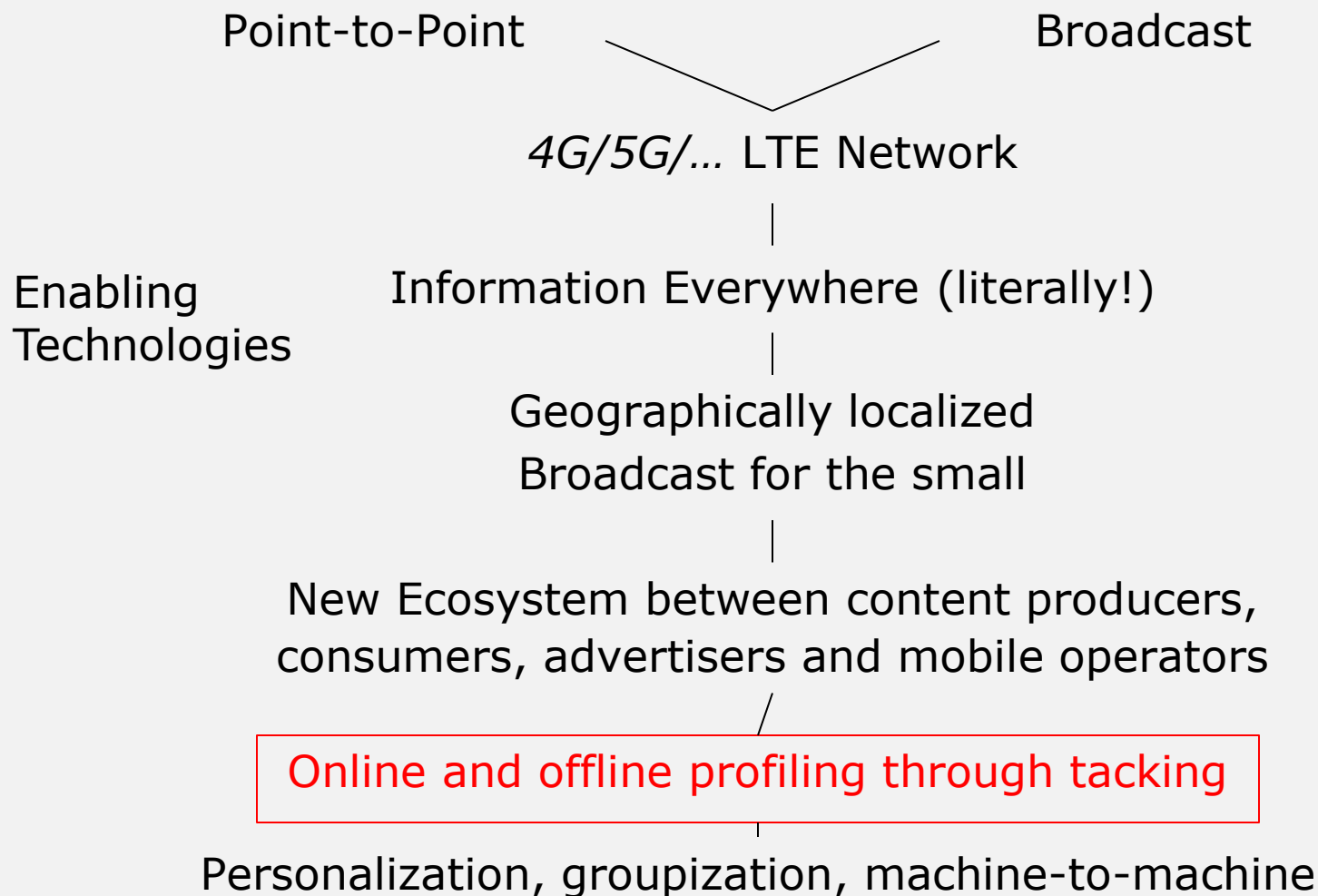
But there are Newborns Every Day

- Google AdWords and AdSense have been significantly expanded to include other media: Mobile ads, search ads, TV ad, etc.
- Other new comers providing ad management platforms:
 - clypd, Flite, inMobi, etc.

Interim Summary: Besides Broadcast

- Broadcast is a media delivery method
 - Concerns more to mobile operators in terms of making good use of expensive bandwidth and creating new revenue
 - Motivates new applications and new business models
- To most end users:
 - Broadcast is the same as multiple point-to-point connections if they do not care about costs
- Besides broadcast, there are other needs and opportunities

Outline

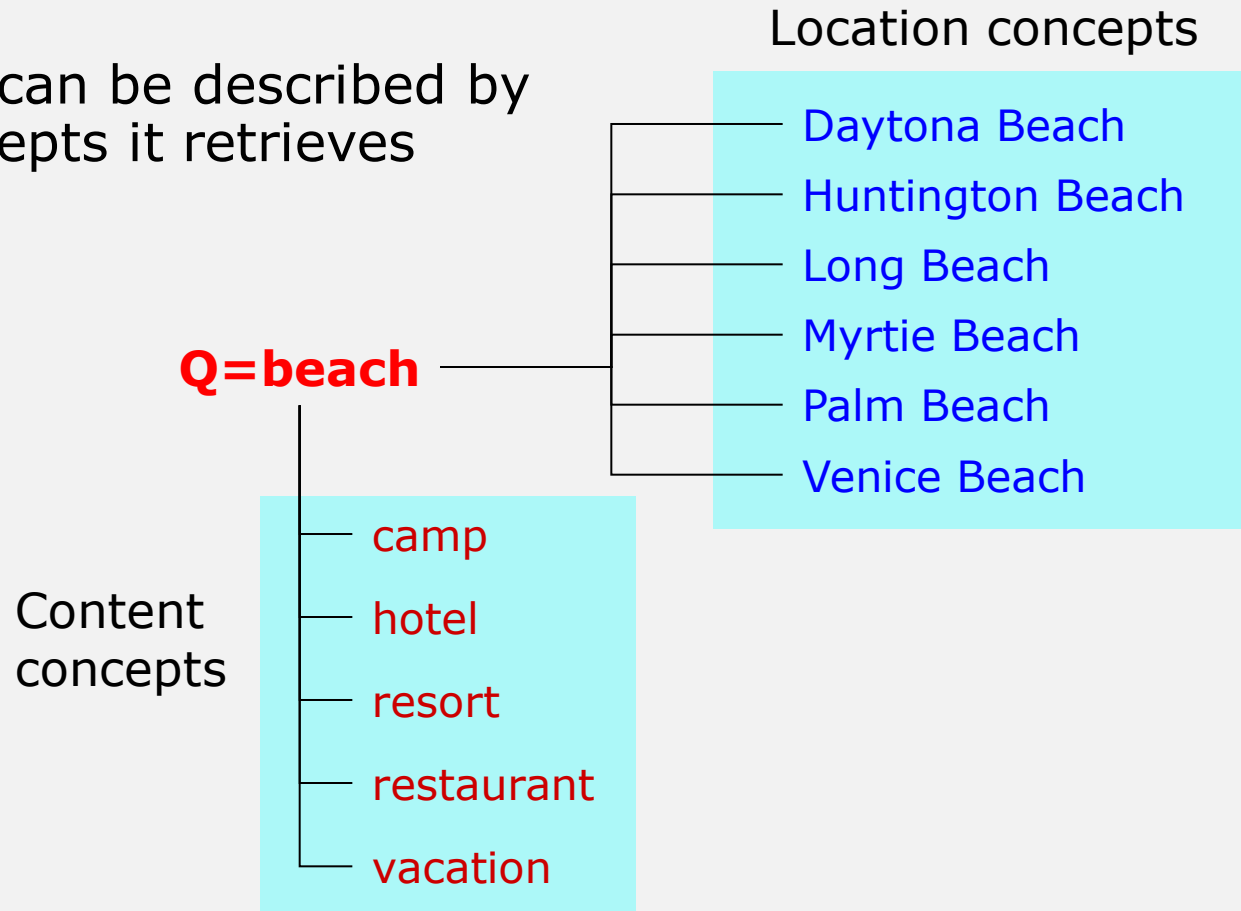


User Interest Identification

- Internet: Search queries, page views, posts, etc.
 - Keywords extracted from search log, viewed pages and posts
 - Classified as content and location concepts
- Using search as an example:
 - Every result is characterized by a set of content and location concepts (feature vector)
 - User clicking on a page affirms the user's interest on the page and hence the content and location concepts in the page
 - As time goes by, a user's interest is represented by a set of content and location concepts (user profile)
 - We want to use the user profile to train a re-ranking function that reorders the search result

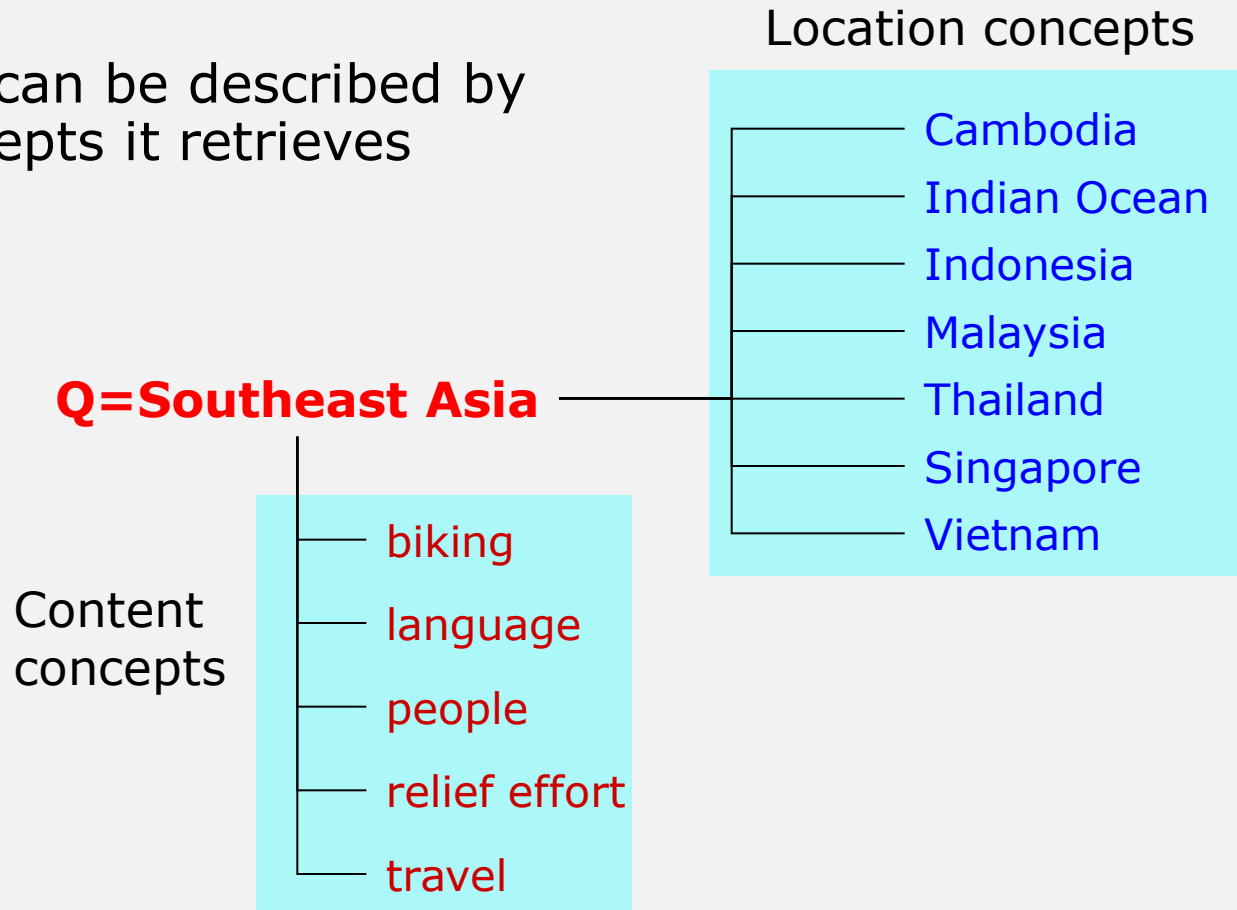
Example 1: Content & Location Concepts

- A query can be described by the concepts it retrieves

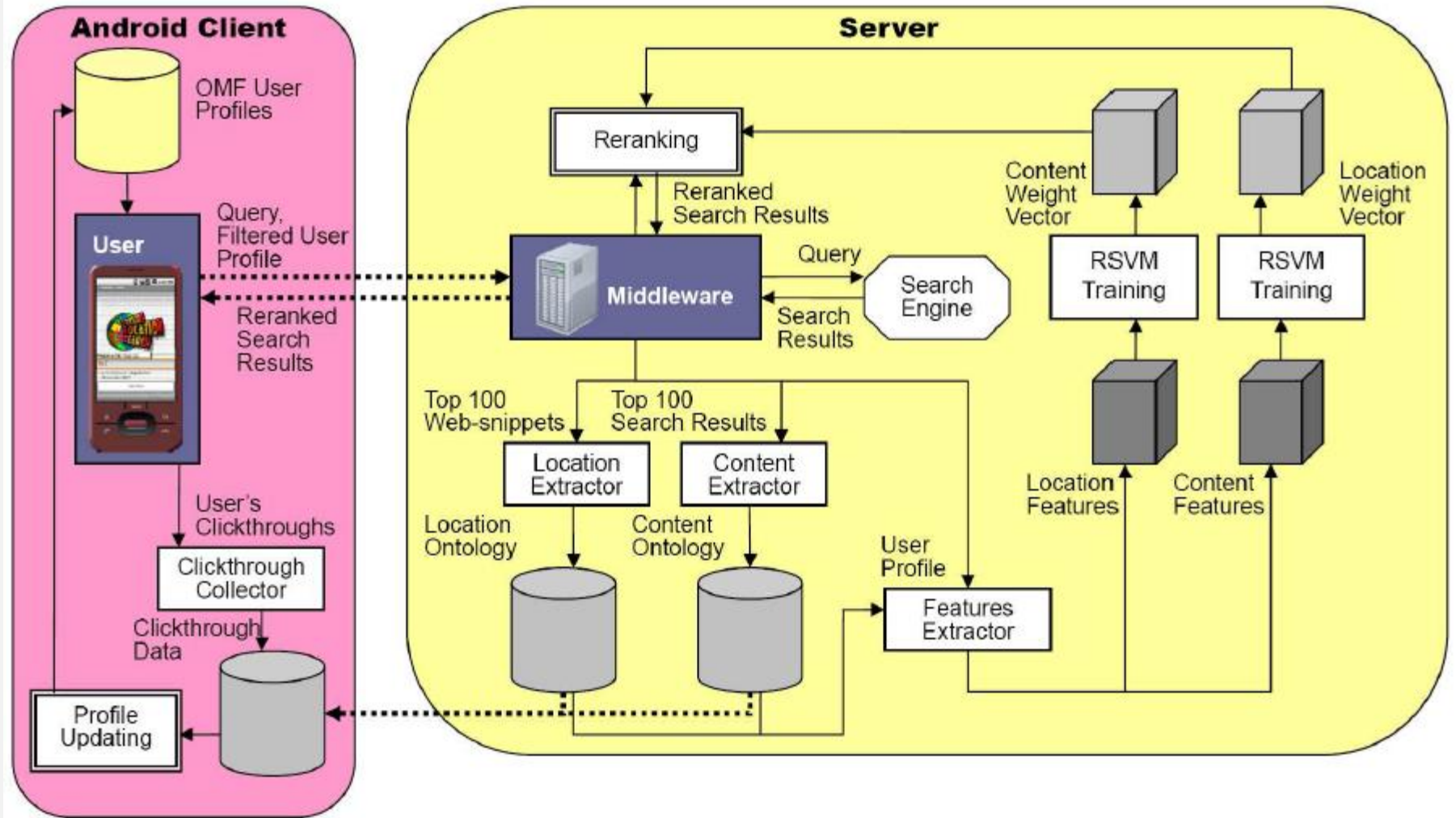


Example 2: Content & Location Concepts

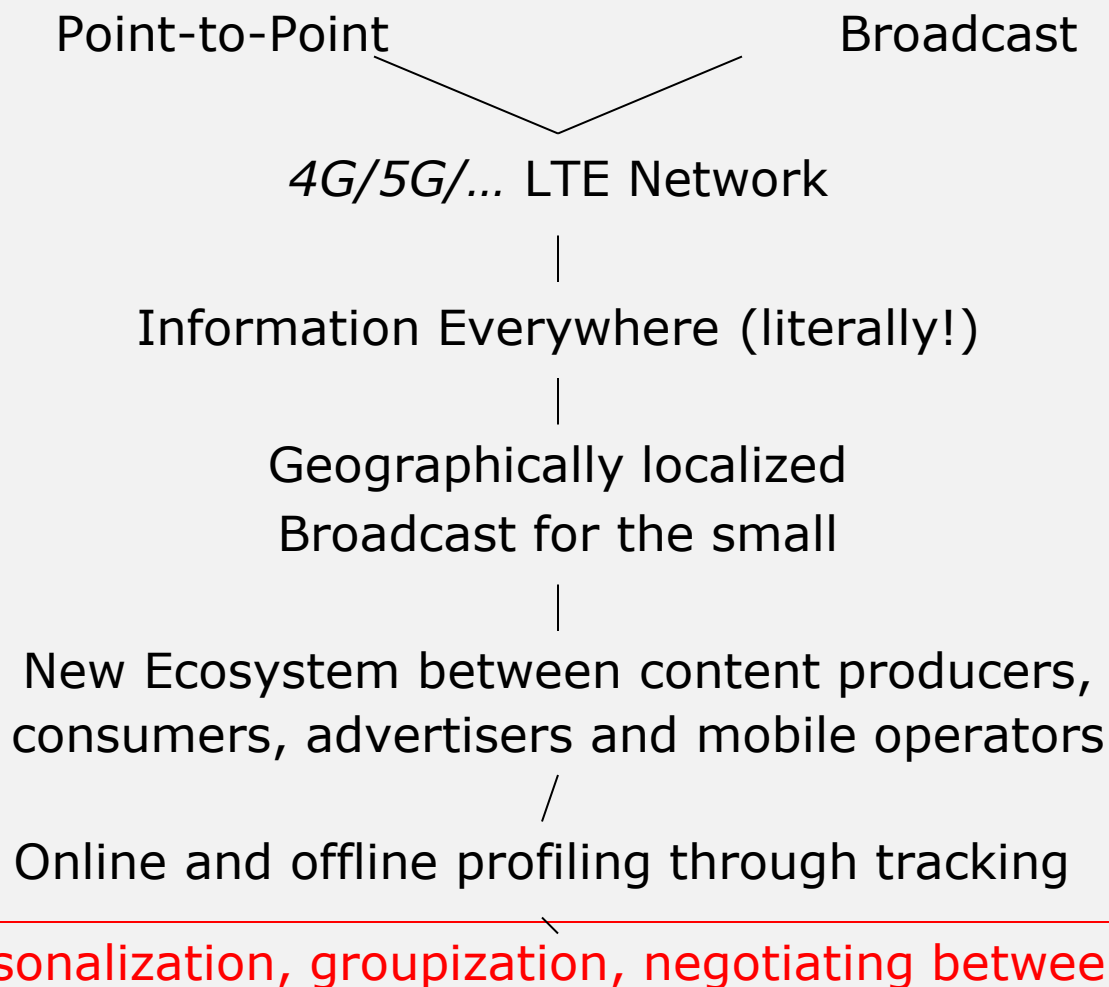
- A query can be described by the concepts it retrieves



A Personalized Search Engine



Outline



Personalization vs Groupization

- Personalization is based on a user's history
 - Personalized search or recommendation could return results that the user is already familiar with
 - Need diversified and yet relevant results and recommendations

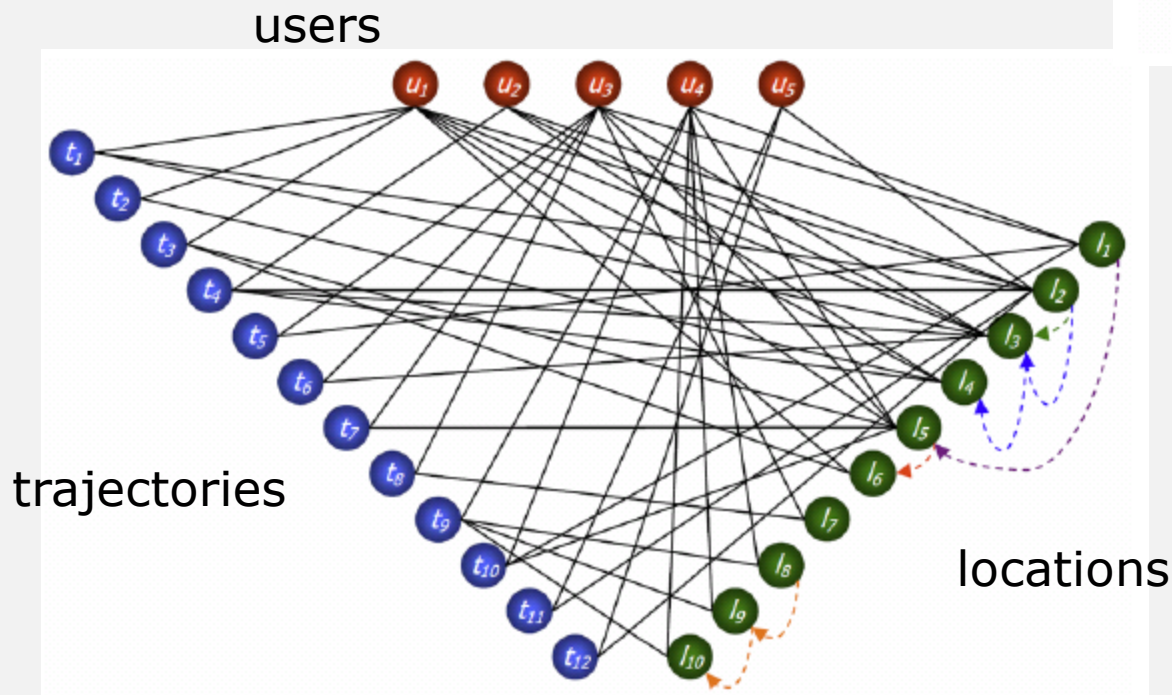
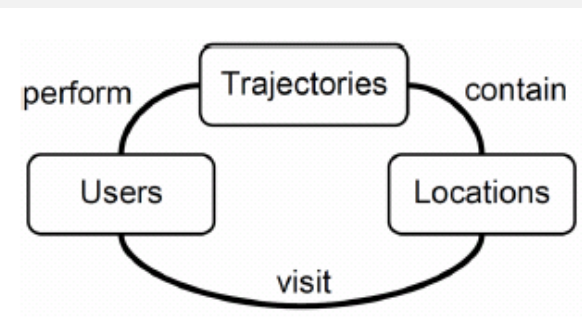
- Groupization is based on collaborative filtering
 - A simple CF method is "People who bought this book also bought these other books"
 - Groupization (or a more complex CF method) is to first establish a user group/community based on common interests
 - Recommendations are based on other group members' actions
 - People similar to you and bought this book also bought these other books

Groupization & Location Recommendation

- ❑ Groupization makes recommendation more relevant even at coarse location granularity
- ❑ People who visited UQ, then to North Quay also visit Riverside
- ❑ People who visited UQ, then to North Quay, then to Riverside also go to boat tour
- ❑ A sequence of coarse locations can identify a group of similar users from who a relevant recommendation can be made

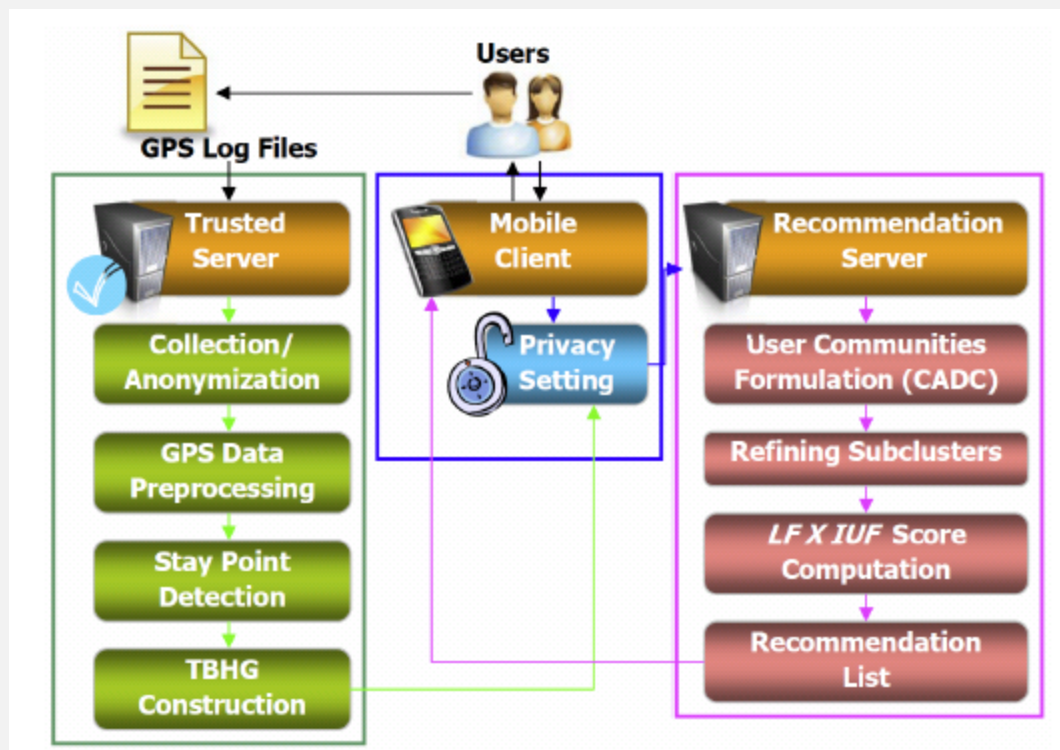
Collaborative Location Model

- Co-clustering method to cluster similar users, similar trajectories and similar locations into groups

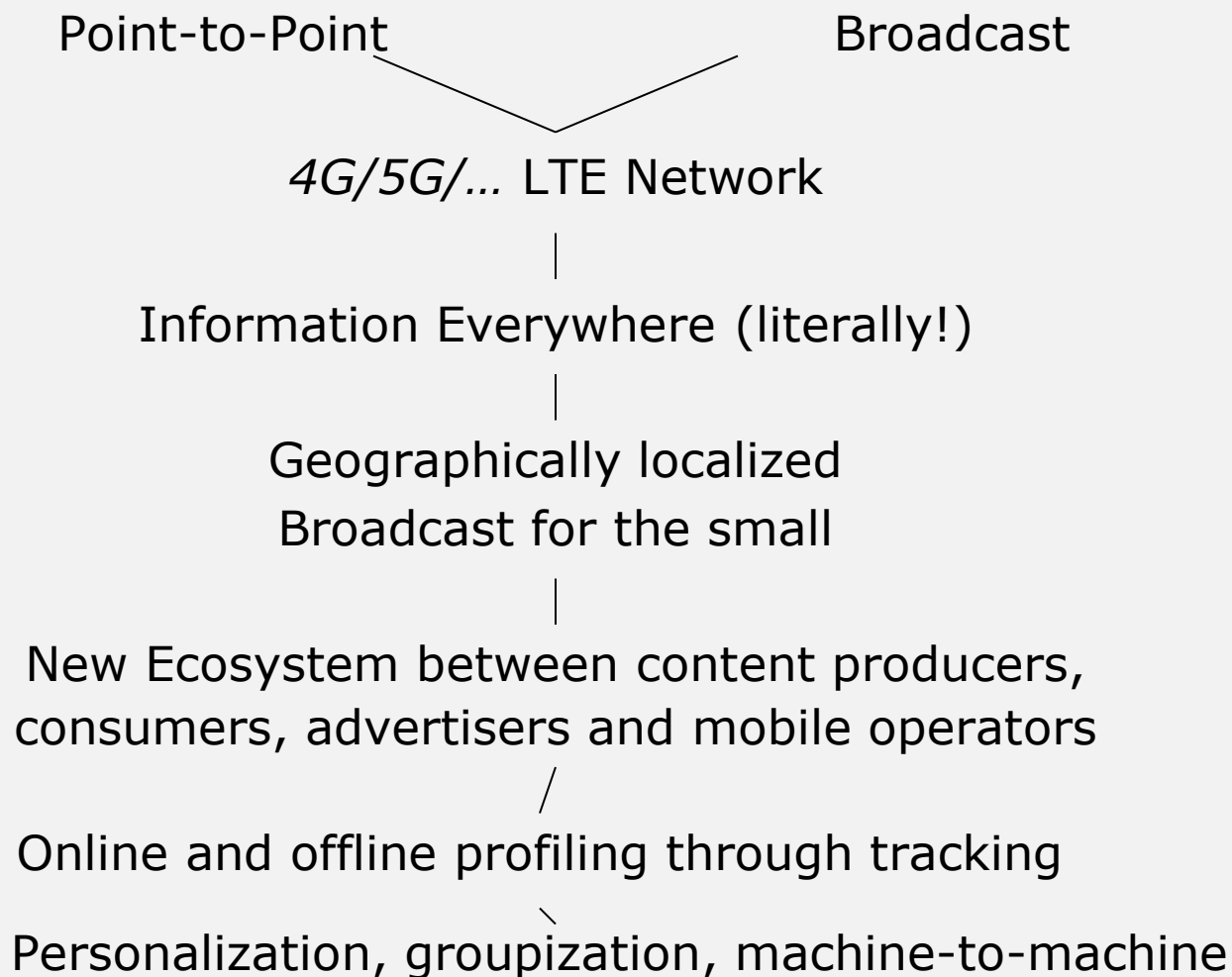


System Components

- ❑ Recommendation server is untrusted since it must be accessible to many users
- ❑ All private data are stored on user device



Outline



Machine to Machine

- ❑ Machines (smart phones) are our proxy
- ❑ Machines have our profiles and contexts (time and location), they can discover, match, filter, acquire, exchange and organize information for us in the background
- ❑ Find 10 nearby restaurants: I found 4 in my area, you found 3 in your area, she found 2 in her area and he found 2 in his area



Summary

Point-to-Point

Broadcast

4G/5G/... LTE Network

Broadcast will become ubiquitous

Cannot afford not to broadcast "something"; hence information is everywhere

Information Everywhere (literally!)

Geographically localized Broadcast for the small

Large amount of multi-type, multi-source information demands extensive profiling

Financed by a new ecosystem

New Ecosystem between content producers, consumers, advertisers and mobile operators

Online and offline profiling through tracking

Personalization, groupization, machine-to-machine