

# Towards Energy-Efficient, Privacy-Aware, Decentralized Device-to-Device Content Delivery



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Engineering Lab (PS)**

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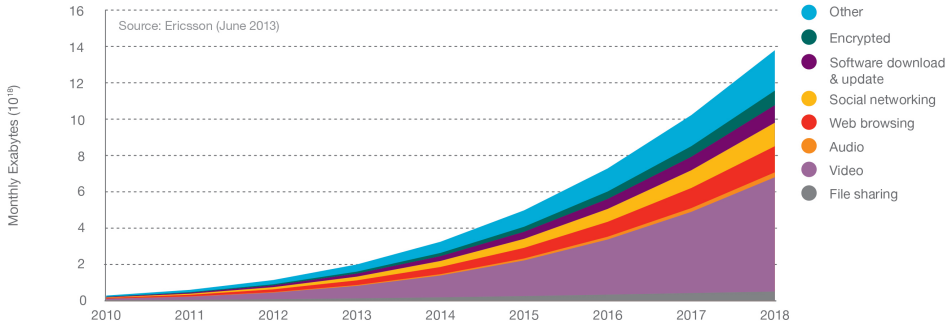
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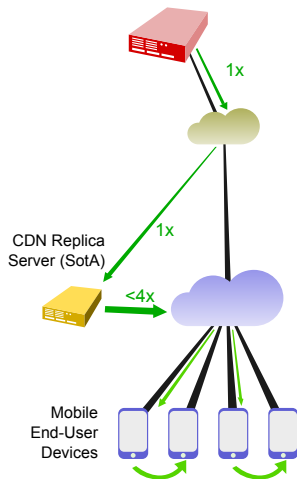
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# Predicted Growth of Mobile Traffic Volume



# Device-to-Device (D2D) Content Delivery

- ▶ Today: Content Delivery Networks (CDNs)
  - ▶ Mobile access network still overloaded
- ▶ D2D Content Delivery: Transmits content from one to another consumer device
- ▶ Direct radio transmission, no intermediate infrastructure
- ▶ Goals:
  - ▶ Reduce access-network infrastructure utilization
  - ▶ Increase Quality of Experience (assuming bandwidth-limited infrastructures)



# D2D Content Delivery Scenario

- ▶ Effective specifically under certain circumstances
  - ▶ Many people/devices around the user
  - ▶ The content is popular
- ▶ D2D Content Delivery combined with consumption prediction
  - ▶ Based on social information or past behavior
  - ▶ Predicted content is pre-fetched whenever discovered in a crowd
- ▶ Example: Commuting by Train
  - ▶ Content predicted to be watched is exchanged at the station/in the train
  - ▶ Later consumed at work/at home



The Crowd For DMB 1 ©Moses  
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Dc metro car interior ©AudeVivere  
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- ▶ Related Work
- ▶ Problem Statement
- ▶ Approach: Energy Efficiency
- ▶ Approach: Privacy
- ▶ Next Steps, Outlook

# Related Work



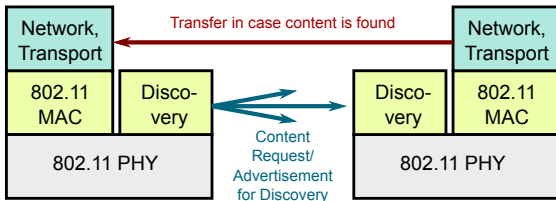
		Central-Server-based ...							
		Content Delivery Networks ...	Energy-aware	Privacy-aware	Multi-Hop Discovery and Delivery	Discovery Layer	Femto-cell-based		
Content Delivery	Device-to-Device Content Delivery	Centralized Disc. (Operator-ctrl'd)	Bao13DataSpotting	yes	yes	no	Licensed, e.g.LTE	no	Operator mediates D2D transfer on certain "hot spots"
			Golrezaei13Femtocaching	yes	yes	no	Licensed, e.g.LTE	yes (one variant)	Operator mediates D2D transfer, knows every D's cont. and pos.
	Decentralized Discovery	Licensed Spectrum	Yu09CellularD2D	no	no	no	Licensed, e.g. LTE	yes (one variant)	Focused on spectral efficiency
			802.15.1 (Bluetooth)	McNamara08MediaSharing	no	no	no	802.15 SDP	no
		802.11-based (WiFi)	Han-eDiscovery	yes	no	no	802.11 802.15	no	Adaptation of 802.11/802.15 windows, beacon intervals etc.
			Custom MAC-based discov.	Boldrini08ContentPlace	no	no	yes	Unknown, abstract	no
		Ma10Cooperative		no	no	yes	Unknown, abstract	no	Theoretical, message-based.
		Ad-Hoc/WiFi-Dir.-based discov.	<b>Our approach</b>	<b>yes</b>	<b>yes</b>	<b>no</b>	<b>802.11 PHY</b>	<b>no</b>	

# Problem: Energy Loss and User Interest Disclosure



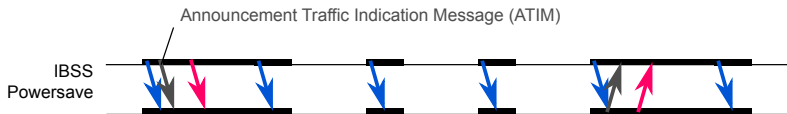
- ▶ Alternatives: LTE, Bluetooth, ZigBee, WiFi
- ▶ Focusing on IEEE 802.11 (WiFi)
  - ▶ Unlicensed, large hardware adoption and wide communication range
- ▶ Current IEEE 802.11 MAC layer designed for
  - ▶ **low-delay**, reliable communication
  - ▶ between devices **previously known to each other** (“connection”)
- ▶ 802.11 for content discovery on spontaneously connected devices:
  - ▶ Variety of **management frames** (beacons, ATIMs)
  - ▶ Unnecessarily frequent / continuous *medium listening*
- ▶ Consequence: **High Energy Consumption**
- ▶ **Disclosure** of user interest to all devices in range
- ▶ **How to make a self-organizing D2D content delivery system energy-efficient and privacy-aware?**

- ▶ Single-hop D2D:
  - ▶ Stability, Medium Availability
  - ▶ Lack of incentives for intermediate nodes
- ▶ Discovery Communication:
  - ▶ Broadcasting link-layer frames in proximity
  - ▶ Agreeing on physical parameters (channel, rate) at roll-out
  - ▶ **Without** previous device scanning, participating in distributed beaconing, handshaking.

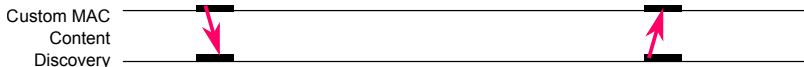




# Energy-Aware Content Discovery - Sleep Cycle Comparison

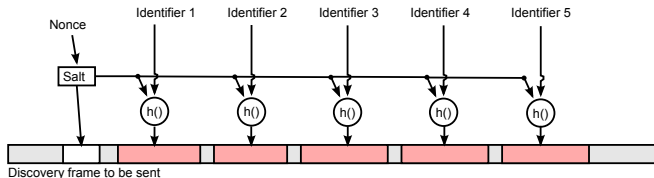


-> Not feasible in spontaneously connected groups: hidden node problem



-> Sleep Synchronization problem

- ▶ Reveal the request only to devices **having** the key.
  - ▶ Salt-Hash Identifiers
  - ▶ Choose a new nonce at every new request.
  - ▶ Hash every clear-text identifier using the nonce as the salt.
  - ▶ Broadcast the hashed identifiers with the nonce.
- ▶ Anonymous Addressing
  - ▶ Randomly chose and frequently change addresses on wireless medium.
  - ▶ Revealing the identity requires signal strength measurements.





### **Self-organizing D2D Content Delivery can be designed more energy-conserving and privacy-aware.**

Next steps:

- ▶ Studying Effectivity
  - ▶ Identify the situation where a D2D content delivery is effective
- ▶ Develop user incentives for providing content
- ▶ Further development to a fully-fledged protocol (MAC/Network layer)
- ▶ Energy- and mobility-aware simulation
- ▶ Prototype implementation

# Questions



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