



HELSINKI UNIVERSITY OF TECHNOLOGY
Networking Laboratory

Mobile Data Service Usage Measurements

Results 2005-2007

Antero Kivi

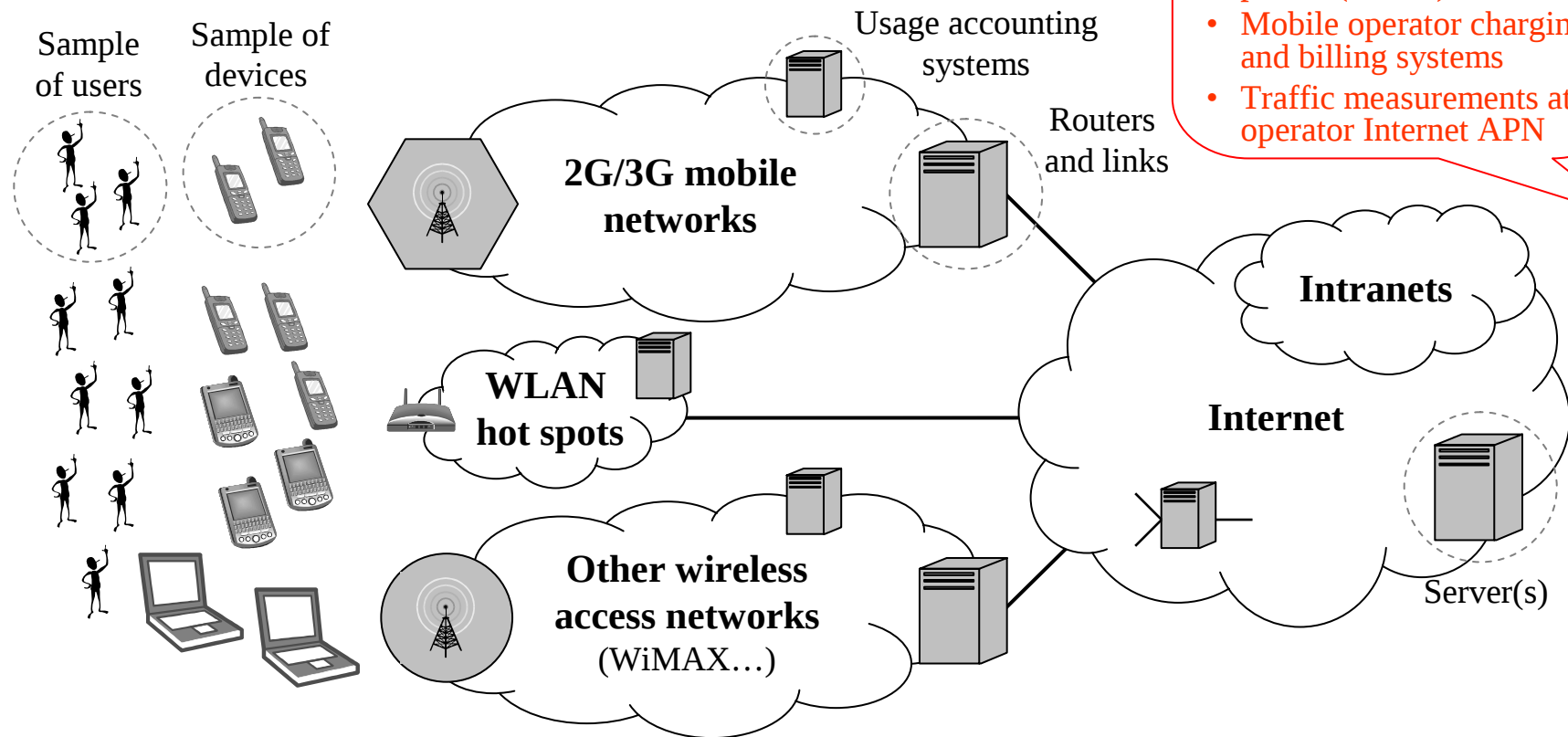
8.4.2008



Sources of data on mobile service usage

OUR RESEARCH

- Surveys on handset panel participants
- Handset monitoring panels (SP360)
- Mobile operator charging and billing systems
- Traffic measurements at operator Internet APN



Source: Kivi, 2007



Major findings

- Data from mobile operators' CDR and subscriber information systems with 80-90% (> 4 000 000) of Finnish mobile subscribers/terminals in falls 2005-2007
 - Finnish mobile terminal base renewing steadily, average age 2,7 years from model introduction
 - Advanced terminal features are spreading, 3G penetration 18% (8% in 2006) and Symbian penetration 18% (12% in 2006)
 - Nokia handsets (>86%) and Nokia's Symbian devices (>99% of smart phones) dominate the handset market
 - 17-19% of mobile terminals generated data traffic weekly, critical mass attained?
 - Total mobile network packet data traffic increased almost 11x, growth mostly from computers although Symbian traffic almost tripled as well
 - Traffic increasingly to/from the Internet (Internet APN: 95% of all traffic)
- 80-90% of Finnish mobile network packet data traffic captured at three mobile operators' Internet APN for a week in falls 2005-2007
 - Computers originate 92% of traffic in mobile network
 - Browsing was the dominant computer application (35%) while the share of P2P traffic was small (4%). A lot of traffic not identified, likely including more P2P traffic
 - Only 4% of network data traffic generated by Symbian devices
 - Web dominates (80%) Symbian traffic, and email is also important (10%)
 - Symbian traffic profile differs from Computer profile, concerning both application profile (web and email) and daily distribution of usage → handset traffic profile largely hidden by Computer traffic
 - Symbian browsing mostly to local (Finnish) content. Daily browsing patterns differ between services of different nature, individual events and special content (e.g. F1 content) have an impact on aggregate browsing patterns



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Operator Reporting System –Based Measurements

Mobile Data Service Usage Measurements



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 - Mobile terminals by feature I
 - Mobile terminals by feature II
 - Mobile terminals by manufacturer
 - Mobile terminals by year of introduction
- Mobile packet data traffic
 - Mobile subscribers by type of subscription
 - Share of active mobile data users
 - Mobile network data traffic
 - Packet data traffic per service
- Summary



Operator reporting system data

Measurement description I

- Data collected using mobile operators' charging-oriented reporting systems in falls 2005-2007
 - Ticket (CDR) and subscriber information systems of Finnish GSM/UMTS operators
 - Data primarily from 2 weeks or 1 month in Sep – Oct, 2005-2007
- About 80-90% of Finnish mobile subscribers/terminals included
 - Operators included: Sonera, Elisa (+Kolumbus), DNA
 - No data on: Saunalahti, TeleFinland, others
 - Very comprehensive sample of over 4 000 000
 - Survey studies with similar results commonly with max 10^3 respondents
 - Most data from all three operators
 - In some rare cases results based on data from two operators



Measurement description II

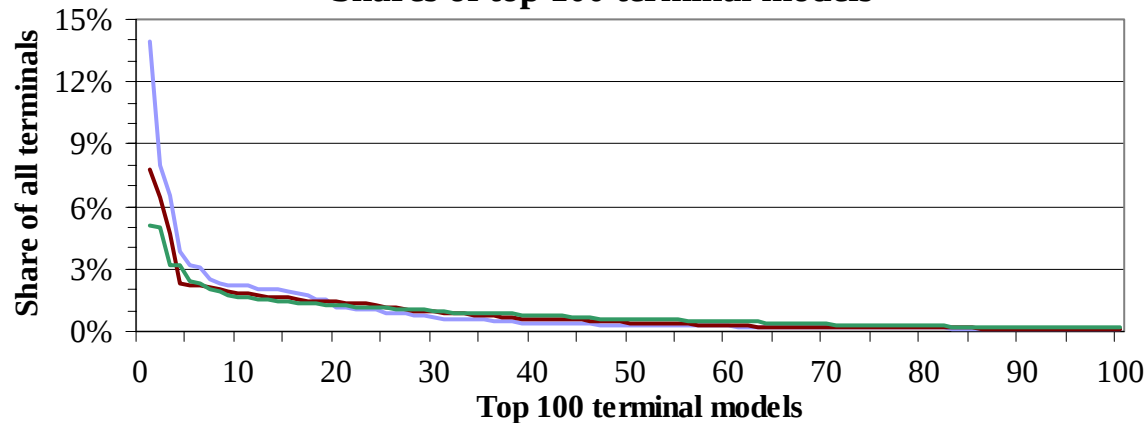
- Terminal base includes all mobile terminals observed at the network during a measurement week
 - Includes: all postpaid/prepaid subscribers' terminals with any transaction (voice call, SMS, packet/circuit switched data traffic...)
 - Some error due to churn and differences in data sets
 - Some error due to unidentified terminals and terminal features
- *Packet data traffic* includes all mobile network packet data traffic transfer by the terminals of all mobile subscribers
 - Includes: basic packet data transfer, roaming, MMS and other separately charged traffic
 - Some differences between operators concerning included traffic
- *Active terminal* is a terminal that has generated packet data traffic during a week



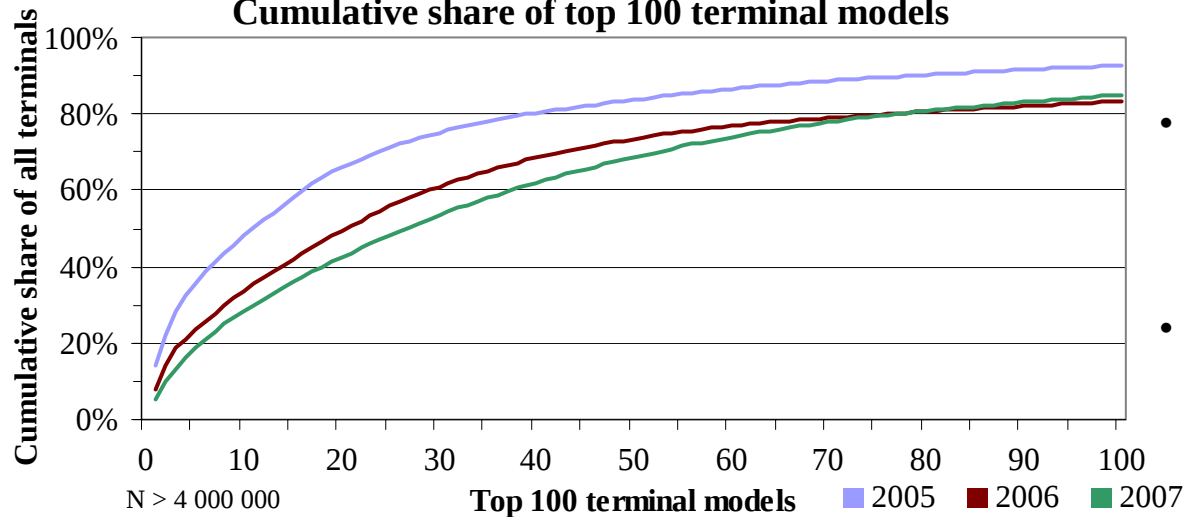
Operator reporting system data

Mobile terminals by model I

Shares of top 100 terminal models



Cumulative share of top 100 terminal models



- Concentration of terminal base still decreasing
 - Share of top 50 in 2007: 67% (2006: 73%, 2005: 84%)
 - Broader handset offering? More models from Nokia, as well as Samsung and Sony-Ericsson
 - Temporary or permanent? Old “hit” models being replaced
- Nokia 3310 still the most popular terminal with 5% share
 - ...as in 2006 (8%) and 2005 (14%)
- Nokia N70 the most popular “high end” handset (ranked 5th), as in 2006
 - N70 most popular camera phone, WCDMA terminal, smart phone...
- Other remarks
 - Roughly 1000 different terminal models identified in total
 - Unidentified terminals likely to increase concentration somewhat



Operator reporting system data

Mobile terminals by model II

Top 10 terminal models (2007)

Rank	Model name	Share of all terminals
1	Nokia 3310	5.1%
2	Nokia 1100	5.0%
3	Nokia 1600	3.2%
4	Nokia 3510i	3.1%
5	Nokia N70	2.4%
6	Nokia 5140i	2.3%
7	Nokia 6060	2.1%
8	Nokia 6101	1.9%
9	Nokia 6630	1.7%
10	Nokia 6021	1.6%

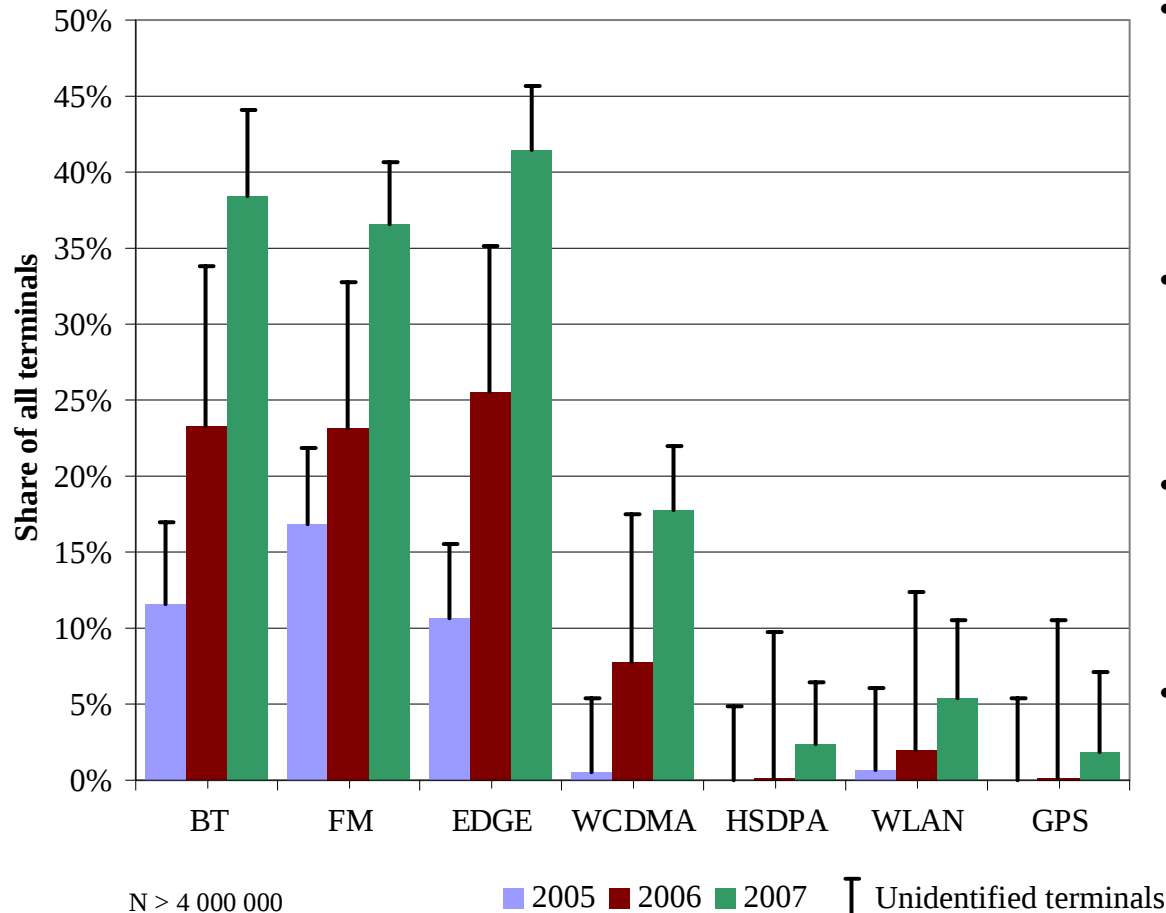
- Top 3 GSM-only telephones with no packet data capabilities
 - Nokia 3310, 1100, 1600
- Top 10 mostly 2G devices, two Symbian 3G models
 - Nokia N70, 6630
- Form factor mostly candybar, two clamshell models
 - Nokia 6060, 6101



Operator reporting system data

Mobile terminals by feature I

Penetration of terminal features



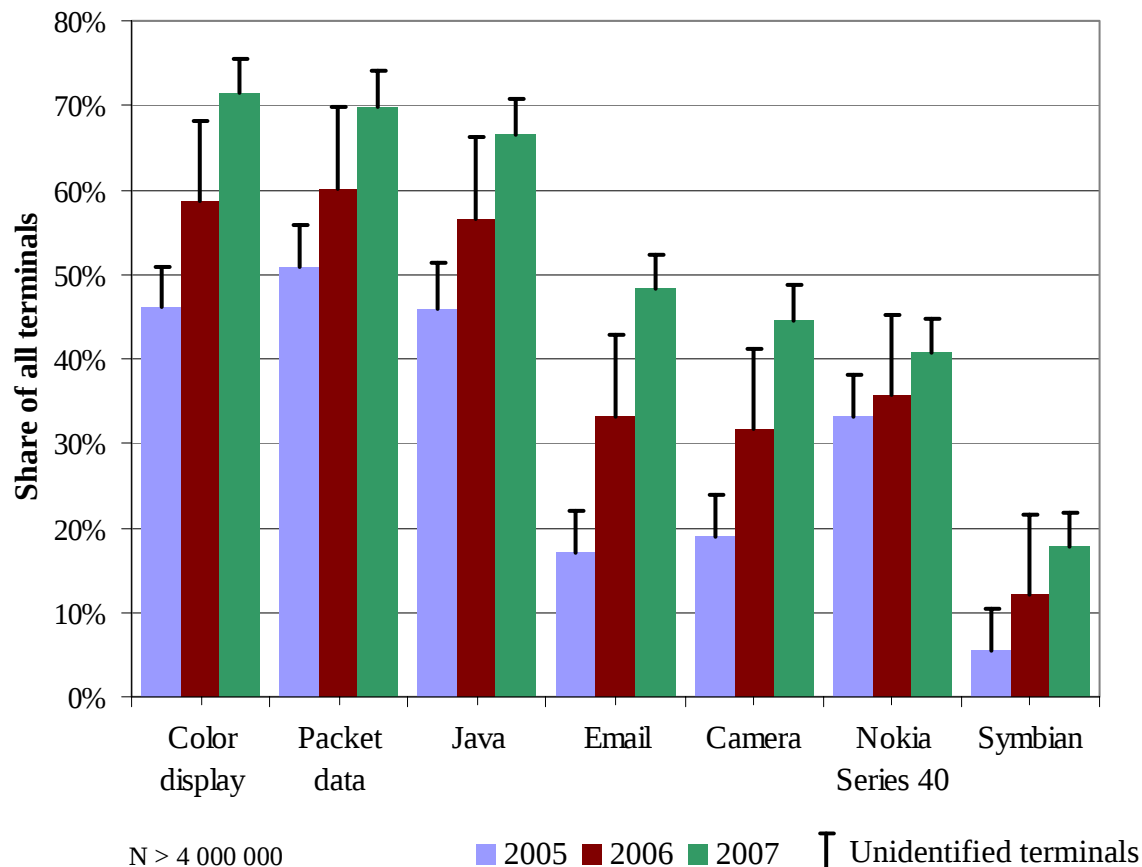
- Key features for mobile packet data usage spreading rapidly
 - EDGE 25 % → 41 %
 - WCDMA 8 % → 18 %
 - HSDPA 0,1 % → 2 %
 - WLAN 2 % → 5 %
- Growth of 3G (WCDMA) especially rapid, due to handset bundling
 - Very steep S curve, growth comparable to more mature features
- Share of non-handsets up to 2,1%
 - From 1,4% (2006) and 0,7% (2005)
 - Data cards and USB dongles, partly explaining rapid HSDPA growth
- Other remarks
 - GPS emerging (2%)
 - Unidentified terminals (τ) increase somewhat penetration of all features (2007: 4-6%, 2006: 10-11%, 2005: 5-6%)



Operator reporting system data

Mobile terminals by feature II

Penetration of terminal features



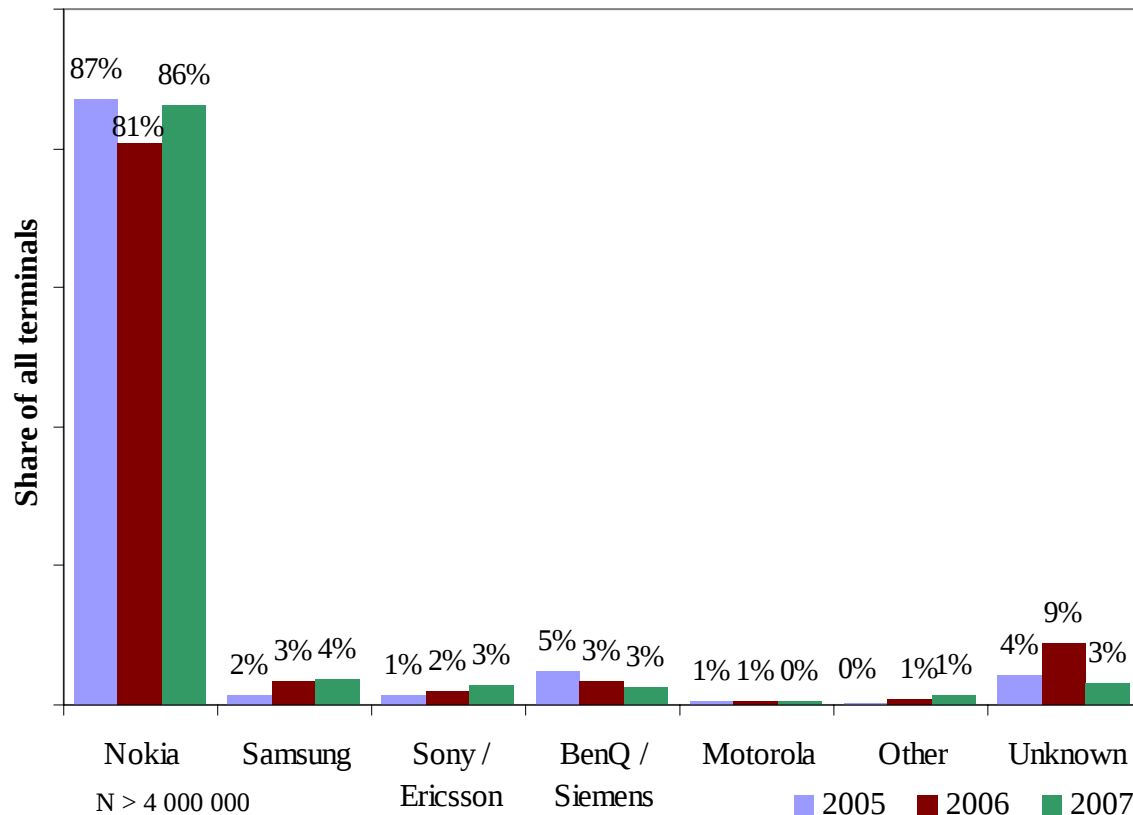
- Color displays, packet data and Java mainstream features
 - ~70% penetration
- Symbian OS in 18% of all mobile terminals
 - S60 growing: 66% → 74% → 84%
 - Series 80 decreasing: 34% → 26% → 15%
 - UIQ marginal: <1%
 - 54% of S60 handsets are 3rd ed. in 2007
- Other advanced OSs (e.g. Windows, Linux, iPhone) marginal



Operator reporting system data

Mobile terminals by manufacturer

Mobile terminals by manufacturer



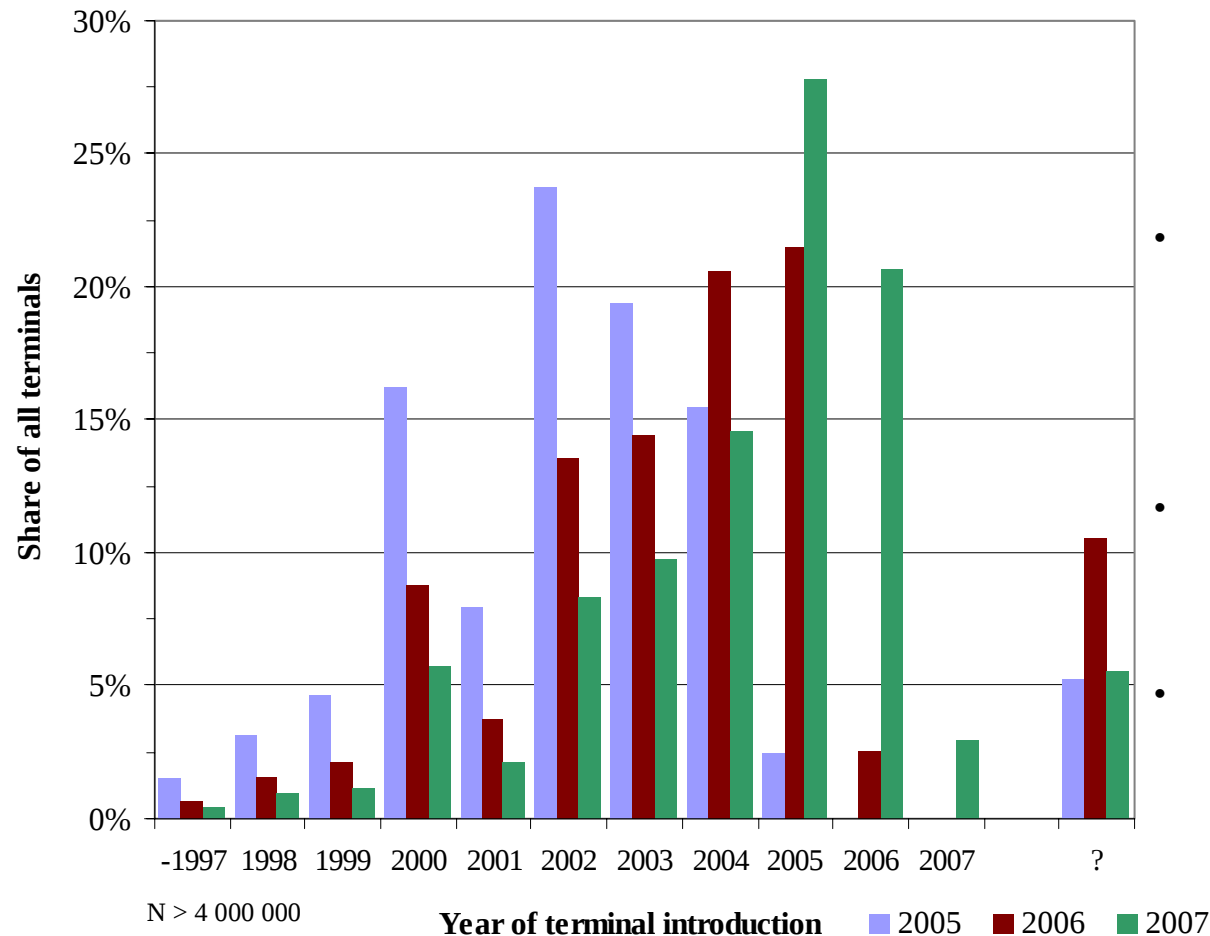
- Nokia's 86% market share remarkable
 - First non-Nokia terminal ranked 57th !
 - I.e. no hit models from other manufacturers
- Samsung and Sony/Ericsson slightly growing
 - BenQ/Siemens and Motorola decreasing
- Nokia dominates smart phone market
 - >99% of Symbian handsets



Operator reporting system data

Mobile terminals by year of introduction

Mobile terminals by year of introduction



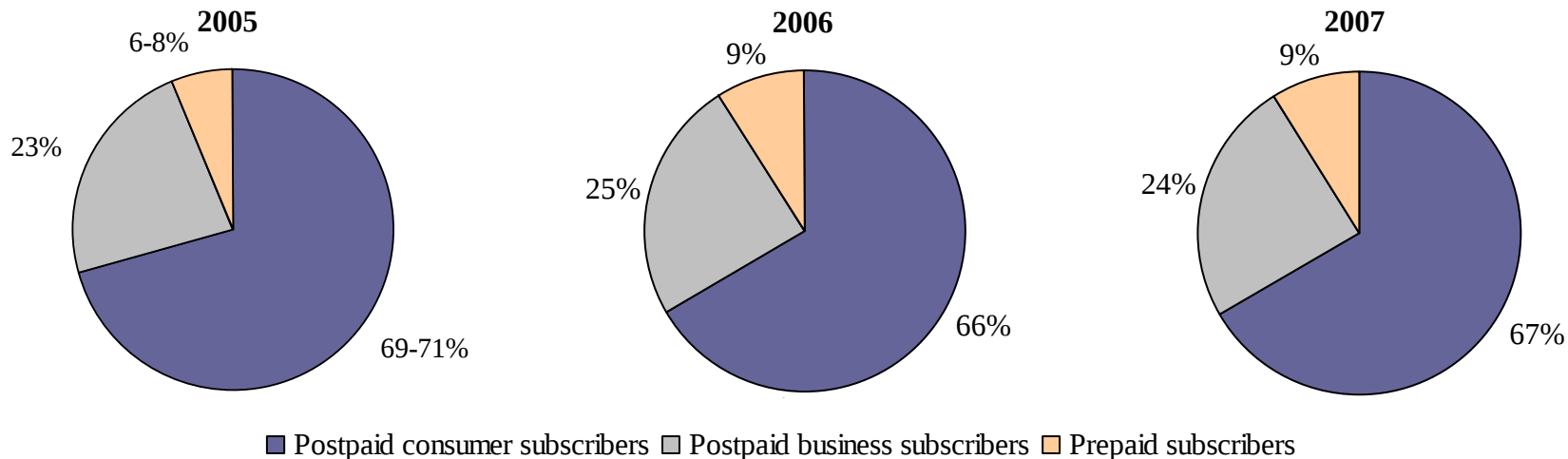
- Mobile terminal base renewing steadily
 - Small change in average age, within margin of error
 - Average "age" up by 1 month: 2,7 years from model introduction in 2007 (2,6 in 2006, 3,0 in 2005)
- Years 2005 and 2001 particular
 - Models introduced in 2005 popular, due to handset bundling and changed market focus towards advanced handsets
 - Fewer or less attractive models introduced in 2001? Models from 2000 and 2002 became more popular...
- What is the effect of handset bundling in terminal base renewal in the long term?
 - Was rapid renewal (2005-2006) one-off?
 - Is current situation new equilibrium level?
- Year of introduction not well defined
 - Data from manufacturer press releases when terminal model announced
 - Delay from introduction to start of sales not stable, depends on e.g. manufacturer, model and market



Operator reporting system data

Mobile subscribers by type of subscription

Mobile subscribers by type of subscription



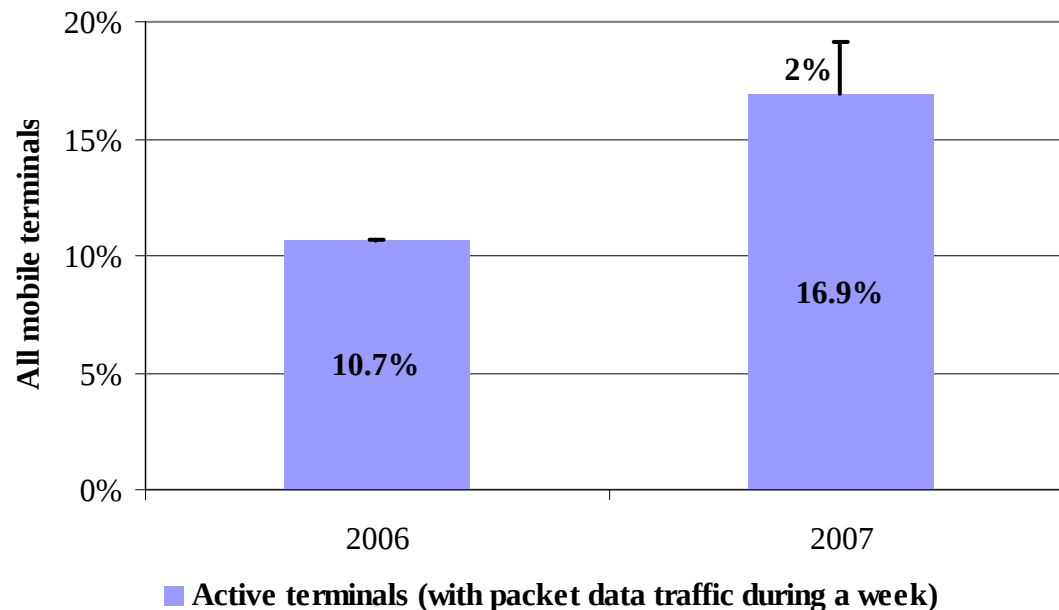
- Shares of different subscription types quite stable
 - Finland still >90% postpaid country
 - Will popularity of mobile broadband subscriptions for data cards etc. affect this?
- Prepaid subscribers with <1% of mobile packet data traffic



Operator reporting system data

Share of active mobile data users

Share of mobile terminals with packet data



N > 4 000 000

┐ Margin of error

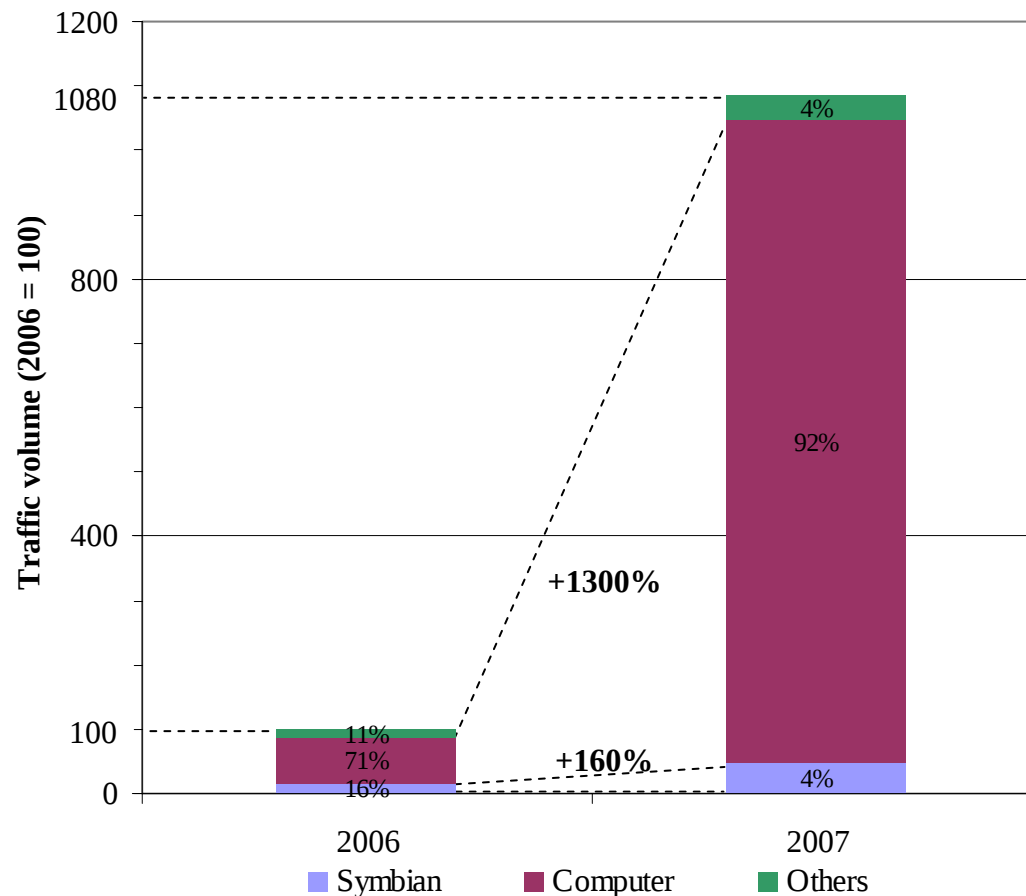
- About 17-19% of mobile terminals generate data traffic weekly
 - Includes all terminal types, share of active handsets $\approx 2\%$ lower
 - Includes terminals of all mobile subscribers (consumer/business, prepaid/postpaid)
 - Postpaid subs. more active than prepaid subs., business subs. more active than consumer subs.
- About 6-8 percentage point increase in share of weekly users
 - I.e. 60-80% more ($\approx 300\ 000$) terminals with packet data traffic
- Is critical mass of mobile data users attained?
 - I.e. after which the number of new users starts growing very rapidly
 - Generally expected to be between 10% and 20%



Operator reporting system data

Mobile network data traffic

Mobile data traffic volume per end-user device



- Very high growth in mobile data traffic
 - Traffic volume almost 11x
 - Statistics Finland*: total mobile network data traffic 100 000 GB in 2006, corresponding to the measured volumes
- Traffic growth mainly by computers
 - Computer traffic 14x, mostly Windows
 - 92% of all Internet bound traffic in mobile networks by computers
 - Data cards, USB modems, handsets as modems via Bluetooth/cable
- Handset traffic growing, but less rapidly
 - Symbian traffic volume almost tripled
 - "Other" traffic mostly unidentified, i.e. computers, handsets and M2M traffic
- Is "mobile Internet" really only about mobile broadband to computers?
 - Handset traffic insignificant in future?
 - Are there any differences between handset and laptop traffic?

* http://www.stat.fi/til/tvie/2006/tvie_2006_2007-06-05_tie_001_fi.html

** Reflects the operating system generating the traffic, not the device with the SIM card. Operating system identified using TCP fingerprinting, see 2nd part of presentation



Operator reporting system data

Packet data traffic per service

- No actual data on service usage besides packet data traffic volumes
 - Traffic predominantly to/from the Internet
 - Internet APN 95% of total packet data traffic volume (89% in 2006)
 - Corporate APNs 4% of total packet data traffic volume (3% in 2006)
 - WAP APN <1% of total packet data traffic volume (7% in 2006)
 - MMS APN share negligible
 - Effect of new data handset services not known, not significant traffic-wise
 - No detailed data on WAP/web, MMS or email usage
 - No data on other operator-provisioned data services, such as mobile TV streaming and music downloading
- See TCP/IP traffic measurements (2nd part of the presentation) for more information on the contents of mobile packet data traffic



Summary

- Data from mobile operators' CDR and subscriber information systems with 80-90% (> 4 000 000) of Finnish mobile subscribers/terminals in falls 2005-2007
- Finnish mobile terminal base renewing steadily, average age 2,7 years from model introduction
- Advanced terminal features are spreading, 3G penetration 18% (8% in 2006) and Symbian penetration 18% (12% in 2006)
- Nokia handsets (>86%) and Nokia's Symbian devices (>99% of smart phones) dominate the handset market
- 17-19% of mobile terminals generated data traffic weekly, critical mass attained?
- Total mobile network packet data traffic increased almost 11x, growth mostly from computers although Symbian traffic almost tripled as well
- Traffic increasingly to/from the Internet (Internet APN: 95% of all traffic)
- PC traffic dominates handset traffic, computers generate at least 92% of Internet traffic



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TCP/IP Traffic Measurements

Mobile Data Service Usage
Measurements



Contents

- Measurement description
 - Measurement scope
 - Measurement setup
 - Identification of terminal operating systems
- Mobile packet data traffic patterns
 - General traffic patterns
 - Traffic by mobile terminal operating system
 - Traffic by application protocol
 - Traffic by day and hour
- Mobile browsing patterns
 - Most popular Symbian web sites
 - Symbian browsing by day and hour
- Summary



TCP/IP traffic

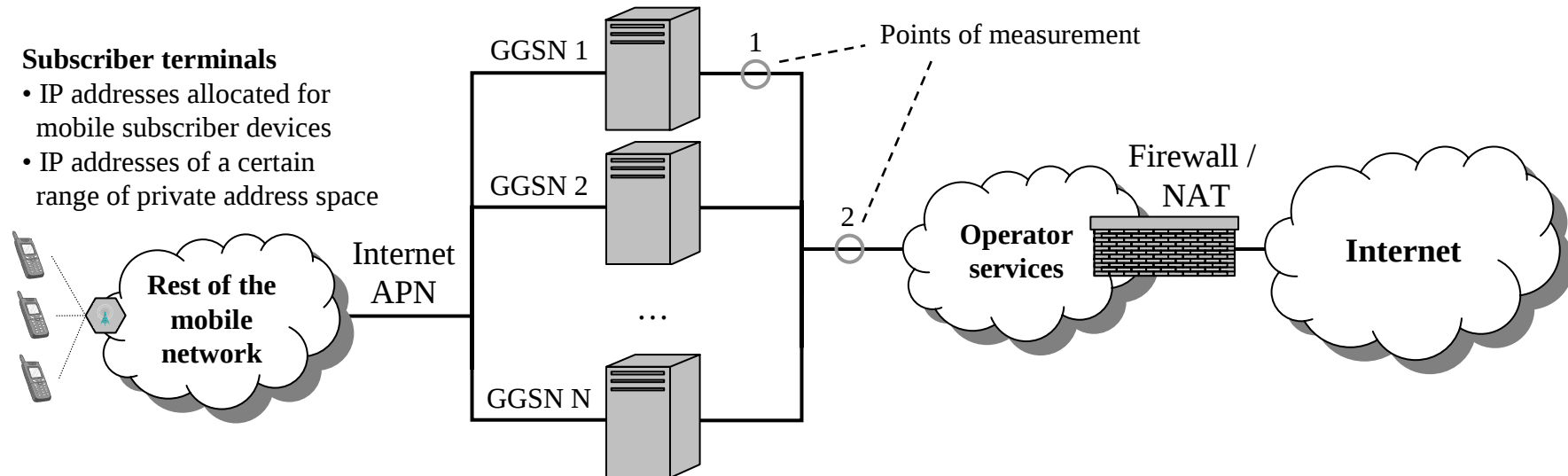
Measurement scope

- Packet data traffic at mobile operator Internet APN measured for a 1-2 weeks in Sep-Oct 2005-2007
 - TCP, UDP and IP protocol headers captured
 - In 2006 and 2007 also headers of other transport layer protocols on top of IP
 - >90% of all packet data traffic (all APNs) goes via Internet APN
 - Measurements at different operators not completely simultaneous
- About 80-90% of Finnish mobile network packet data traffic included
 - Operators included Sonera, Elisa (+Kolumbus), and DNA
 - No data on: Saunalahti, TeleFinland, others
 - In 2005, measurements only at Sonera and DNA → 50-60% of all traffic
 - All traffic to/from Internet by all mobile subscribers (postpaid and prepaid subscribers, business and consumer subscribers)



TCP/IP traffic

Measurement setup



- Measurement points comparable
 - Traffic quantities (bytes, flows) of measurement 1 multiplied by the actual number of GGSNs in order to have proper weight for the operator's traffic
- Measured traffic not influenced by roaming, as home GGSN roaming is used by both operators
 - All roaming traffic by operators' subscribers routed via home network GGSN → all packet data roaming traffic by operators' subscribers included, no foreign roamers' traffic included
- Client and server "roles" identified using terminal IP addresses
 - Subscriber (client) terminals always in specific IP addresses, all other IP addresses considered servers
 - Problem: public IP addresses for mobiles → client-server roles sometimes reversed



TCP/IP traffic

Identification of terminal operating systems

- Terminal operating system (OS) identified using *TCP fingerprinting*
 - I.e. not based on CDRs/tickets and terminal TAC codes
 - Differences in implementation of TCP/IP stack in different OSs → distinct TCP "fingerprints"
 - Traffic traces are compared to the fingerprints of previously identified OSs
 - Common PC and smart phone OSs can be identified with sufficient accuracy
- Operating system identification process includes some possible bias



TCP/IP traffic

General traffic patterns

- Traffic volume grown about 11x between the measurements in 2006 and 2007
 - Statistics Finland*: total mobile network data traffic 100 000 GB in 2006, corresponding to the measured volumes
- Traffic dominantly TCP, the rest mostly UDP
 - 2007: 94% of byte volume
 - 2006: 88% of byte volume
 - 2005: 84% of byte volume
- Traffic dominantly towards the mobile terminals (downlink)
 - 2007: 63% of byte volume (78% for Symbian handsets)
 - 2006: 73% of byte volume
 - 2005: 84% of byte volume
- Other protocols <1% of total traffic volume
 - Mainly IPsec ESP traffic (VPN), >70% of other protocols
 - Excluded from the rest of the analyses

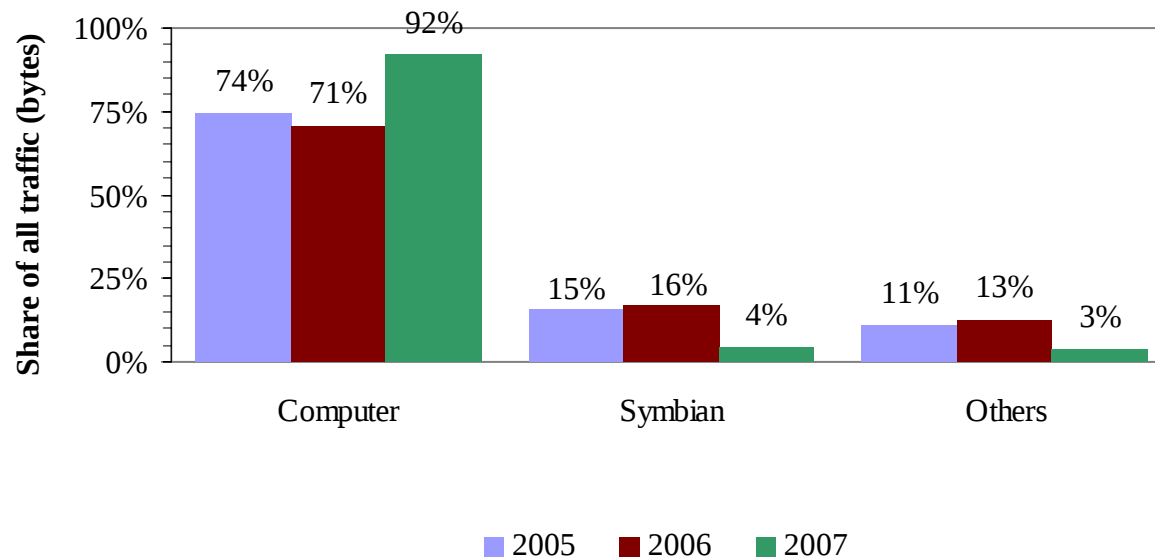
* http://www.stat.fi/til/tvie/2006/tvie_2006_2007-06-05_tie_001_fi.html



TCP/IP traffic

Traffic by mobile terminal operating system

Traffic by terminal operating system



- Computers originate 92% of traffic in mobile network!
 - Data cards, USB modems, handsets as modems via Bluetooth/cable
 - One PC creates more traffic than several mobiles → OS identification necessary to uncover handset traffic
- About 4% of traffic made with Symbian handsets
 - Relative share decreasing, but still a 160% growth in traffic volume



TCP/IP traffic

Identification of application protocols

- Application protocols identified with server-side TCP and UDP port numbers
 - Nearly all 65000 TCP and UDP ports observed
 - Port number based identification not full proof
 - Applications using port space dynamically, or masquerading as other protocols (e.g. P2P, streaming...)
 - Subscriber terminals also as servers as public IP addresses used → client ports observed
- Application protocols (i.e. port numbers) grouped into 5 categories
 - Web, Email, P2P / File transfer, and Others / Unidentified
 - Application protocols that were identified but did not form significant categories → Others
 - Share of Unidentified application protocols significant and increasing

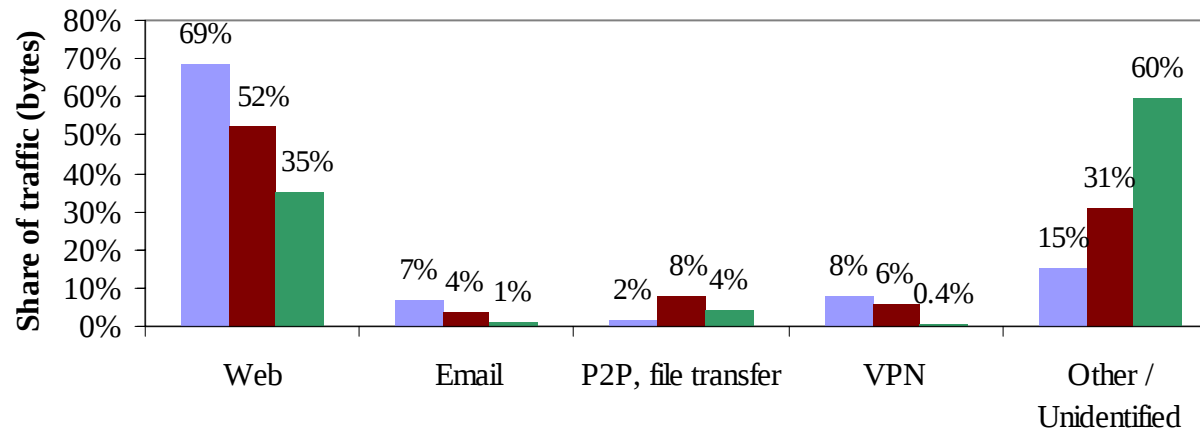
Application protocol category	Major transport protocol ports included	
Web	TCP	HTTP (80), HTTPS (443), HTTP Alternate (8080)
Email	TCP	POP3 (110), IMAP (143), SMTP (25), IMAP/SSL (993), POP3/SSL (995)
P2P / File transfer	TCP	4662, 7777, 6881, 1412, 20, 9999, 6346, 411, 6882, 412
VPN	TCP	10000, 500
	UDP	2746, 10000, 4500, 500, 1194



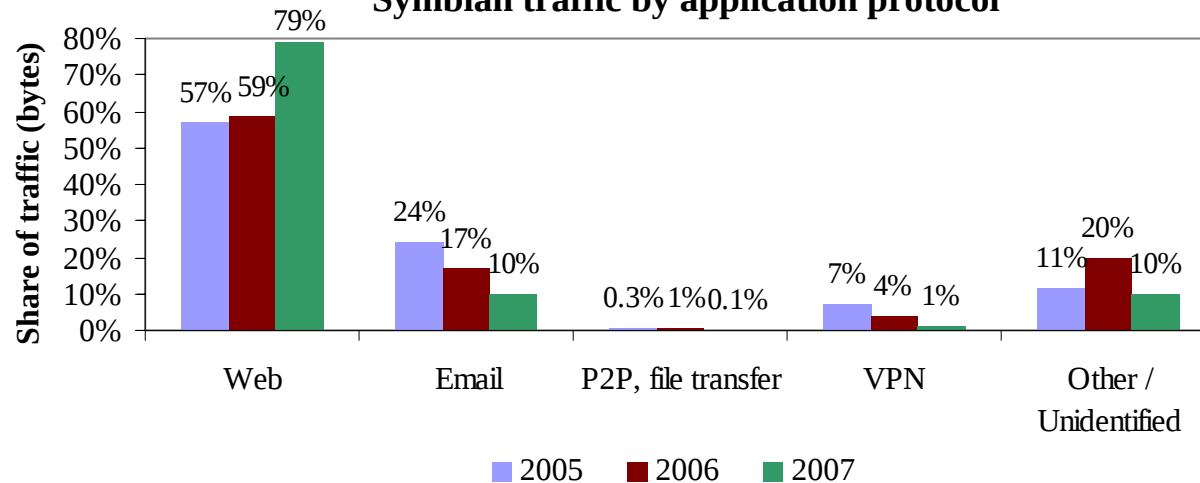
TCP/IP traffic

Traffic by application protocol

Computer traffic by application protocol



Symbian traffic by application protocol



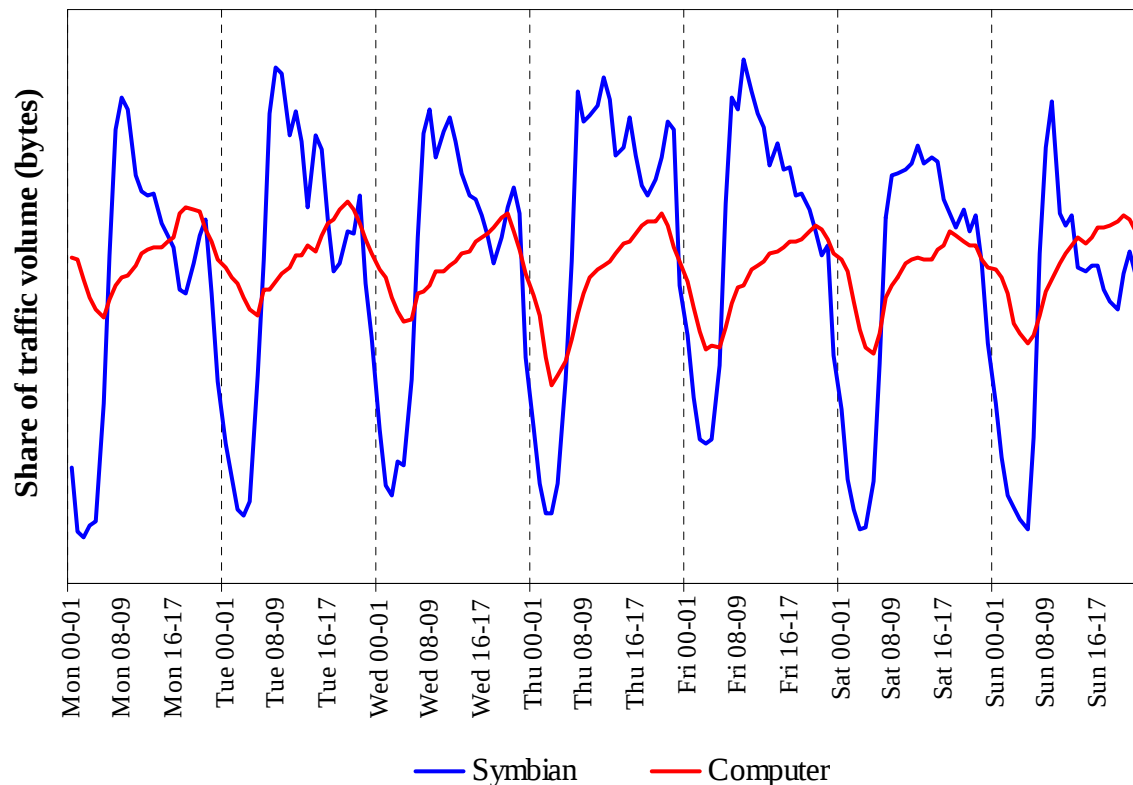
- Computer profile as the profile for all traffic
 - Imposes itself with its dominant traffic share
- Web and email driving traffic growth on Symbian
 - Web and unidentified traffic major categories for computers
- Symbian profile differs from Computer in some ways
 - Email and web more important
 - P2P and unidentified traffic (P2P?, VPN?) much smaller



TCP/IP traffic

Traffic by day and hour (1/3)

Traffic by day and hour (2007)



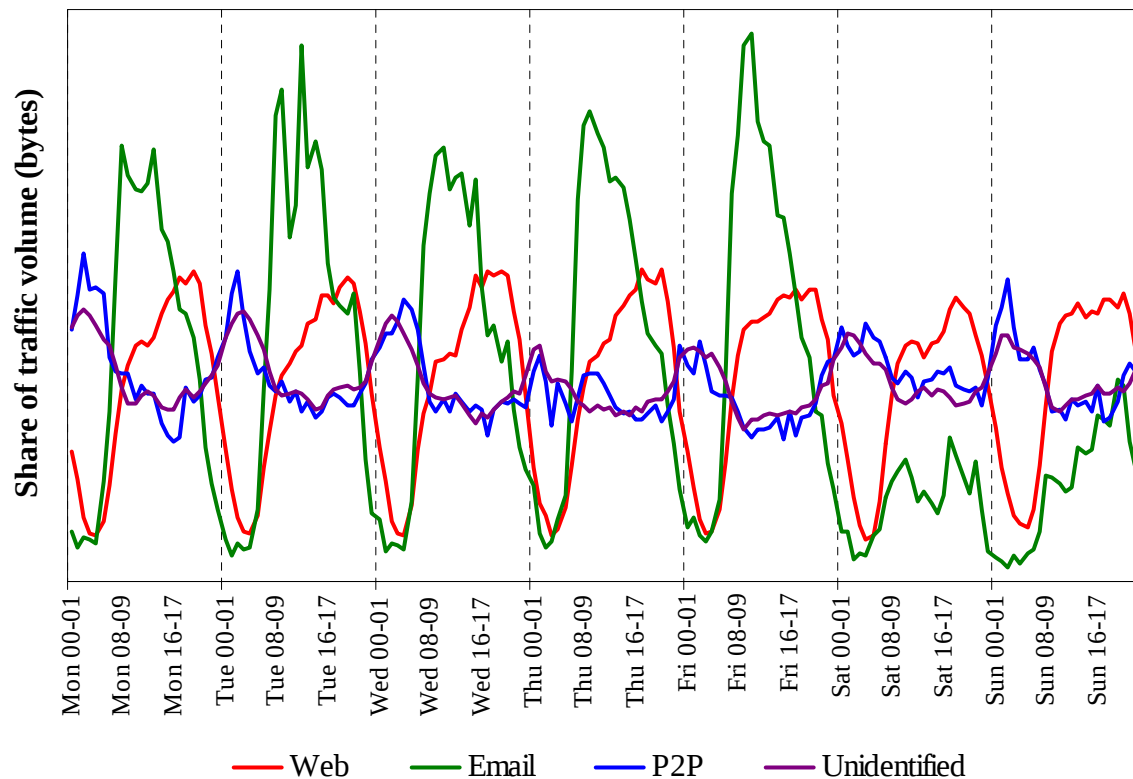
- Handsets and computers have different traffic profiles!
 - High variations in handset traffic during the day
→ reflects human activity?
 - Computer traffic more evenly distributed over the day
→ continuous traffic?
- Handset traffic peaks in the morning (7-10AM), Thursday and Friday the busiest days
- Computer traffic peaks in the evening (6-9 PM), traffic evenly spread over all days of the week



TCP/IP traffic

Traffic by day and hour: Computers (2/3)

Computer traffic by day and hour (2007)



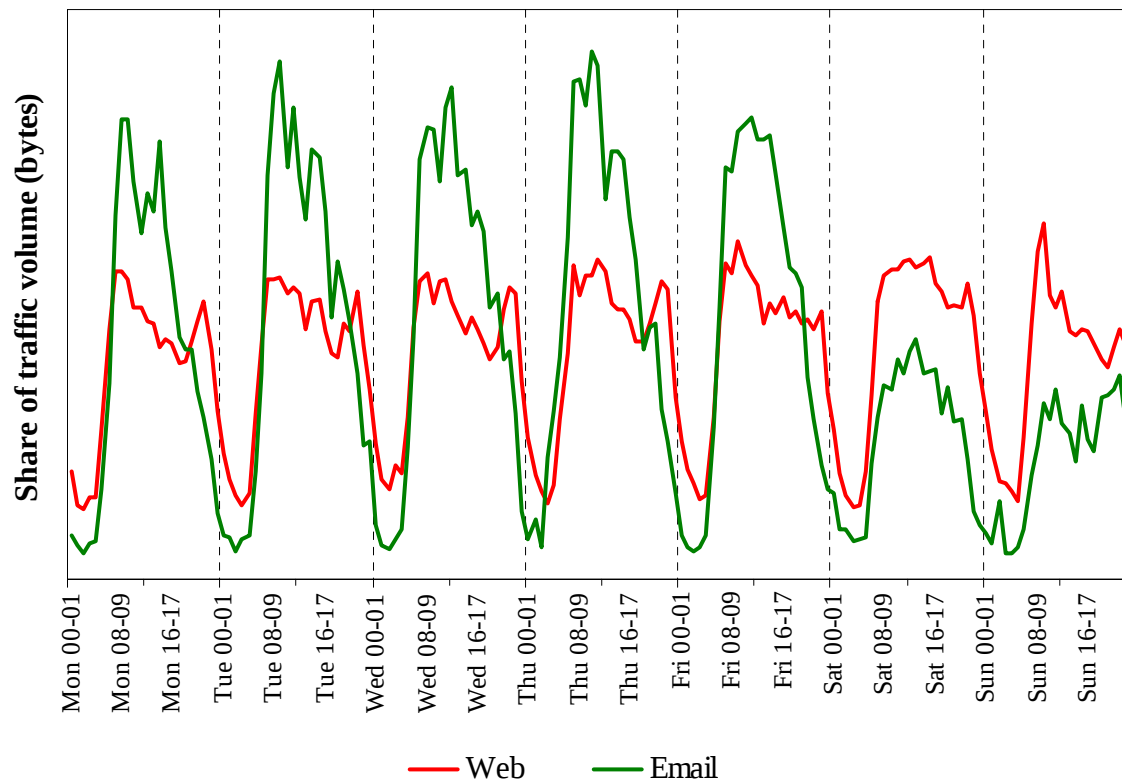
- Email used dominantly in the morning (8-10 AM), significantly less traffic in the weekend
 - Similar patterns observed for VPN traffic
 - Work-oriented services?
- Web browsing with less variation, peaks in the evening (5-9 PM) and no major difference between days of the week
 - Used for both business and leisure?
- P2P and unidentified traffic with very similar profiles
 - Is unidentified traffic (>50% of all computer traffic) P2P as well?
- P2P and unidentified traffic quite stable throughout the week, peak during the night!
 - More capacity available in the network?
 - Prioritization of traffic during the day?
 - Scheduled traffic?



TCP/IP traffic

Traffic by day and hour: Symbian (3/3)

Symbian traffic by day and hour (2007)



- Web and email the major handset traffic categories
 - 90% of all Symbian traffic
- Email traffic highest in the morning (8-12 AM), as with computers
 - Weekend traffic again significantly smaller
 - Work-orientation?
- Web traffic quite even over the waking hours, peak in the morning (7-12 AM)
 - Again, no major difference between weekdays
 - Peak hours differ from computer browsing
 - Computer preferred to Symbian while browsing (at home?) in the evening



TCP/IP traffic

Identification of web domain names

- Browsing: TCP traffic to/from server ports 80 and 443
 - HTTP (80) and HTTPS (443), other ports were omitted as such traffic volume was insignificant
 - Might include P2P or malware traffic as well (traffic to e.g. port 80 goes through firewalls)
- DNS queries captured and associated to web server IP addresses



TCP/IP traffic

Most popular Symbian web sites

Rank	Domain name of site*	Share of web traffic volume
1	mtv3.fi	4.0%
2	iltalehti.fi	3.7%
3	suomi24.fi	2.9%
4	nokia.com	2.9%
5	yle.fi	2.6%
6	google.com	1.9%
7	kauppalehti.fi	1.7%
8	gate5.de	1.4%
9	subtv.fi	1.2%
10	sihteeriopisto.net	1.1%
11	irc-galleria.net	1.1%
12	seksitreffit.fi	1.1%
13	omakuva.org	1.1%
14	genimap.com	1.0%
15	nettiauto.com	1.0%
16	sok.fi	0.9%
17	nokia.fi	0.8%
18	veikkaus.fi	0.8%
19	mobimate.com	0.7%
20	youtube.com	0.6%

- Browsing not very concentrated
 - Traditional media 16.2%
 - Social media 6.3%
 - Adult content 6.3%
 - Nokia sites 5.6%
 - Web portals/search 3.4%
 - Mobile operator 3.3%
 - Mobile content 3.2%
- Mobile web content mostly local
 - Finnish media houses, businesses, social media and adult content providers
 - Non-Finnish content mostly mobile/Internet related

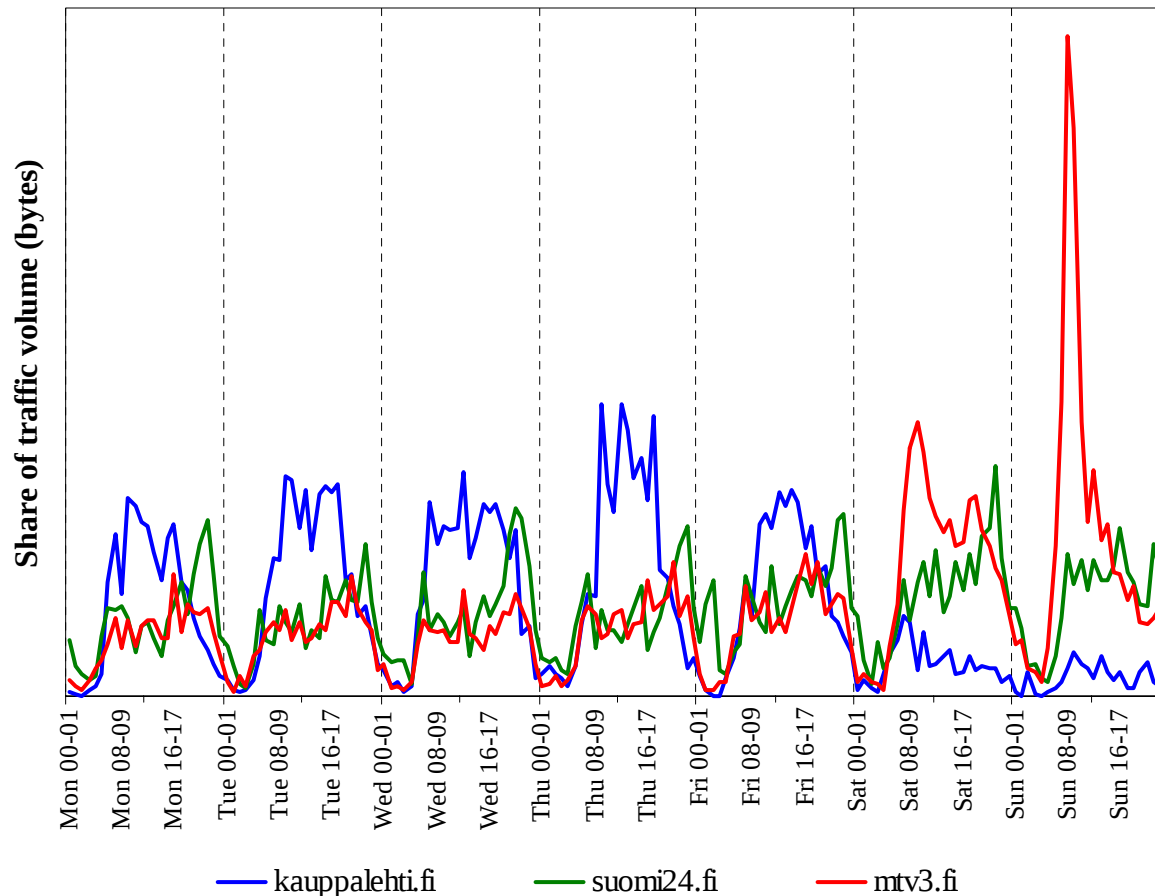
* Mobile operator sites not included



TCP/IP traffic

Symbian browsing by day and hour

Symbian browsing traffic to selected domains by day and hour (2007)



- Individual events and special content matter!
 - Peaks at mtv3.fi coincide with a Formula 1 GP qualifications (Sat) and race (Sun)
 - Otherwise, mtv3.fi content (news, entertainment) accessed in the evening
- Clear differences between services of different nature
 - Discussion forums (suomi24.fi) mostly in the evening and on weekends
 - Business news (kauppaalehti.fi) on office hours and working days, less on evenings and weekends



TCP/IP traffic

Summary

- 80-90% of Finnish mobile network packet data traffic captured at three mobile operators' Internet APN for a week in falls 2005-2007
- Computers originate 92% of traffic in mobile network
- Browsing was the dominant computer application (35%) while the share of P2P traffic was small (4%). A lot of traffic not identified, likely including more P2P traffic
- Only 4% of network data traffic generated by Symbian devices
- Web dominates (80%) Symbian traffic, and email is also important (10%)
- Symbian traffic profile differs from Computer profile, concerning both application profile (web and email) and daily distribution of usage → handset traffic profile largely hidden by Computer traffic
- Symbian browsing mostly to local (Finnish) content
- Daily browsing patterns differ between services of different nature, individual events and special content (e.g. F1 content) have an impact on aggregate browsing patterns



Further information

- COIN and MoMi research project web sites
 - <http://www.netlab.tkk.fi/tutkimus/coin/>
 - <http://www.netlab.tkk.fi/tutkimus/momi/>
- Contact [antero.kivi\(at\)tkk.fi](mailto:antero.kivi(at)tkk.fi)