HELSINKI UNIVERSITY OF TECHNOLOGY
Networking Laboratory

Mobile Data Service Usage Measurements

Results 2005-2006

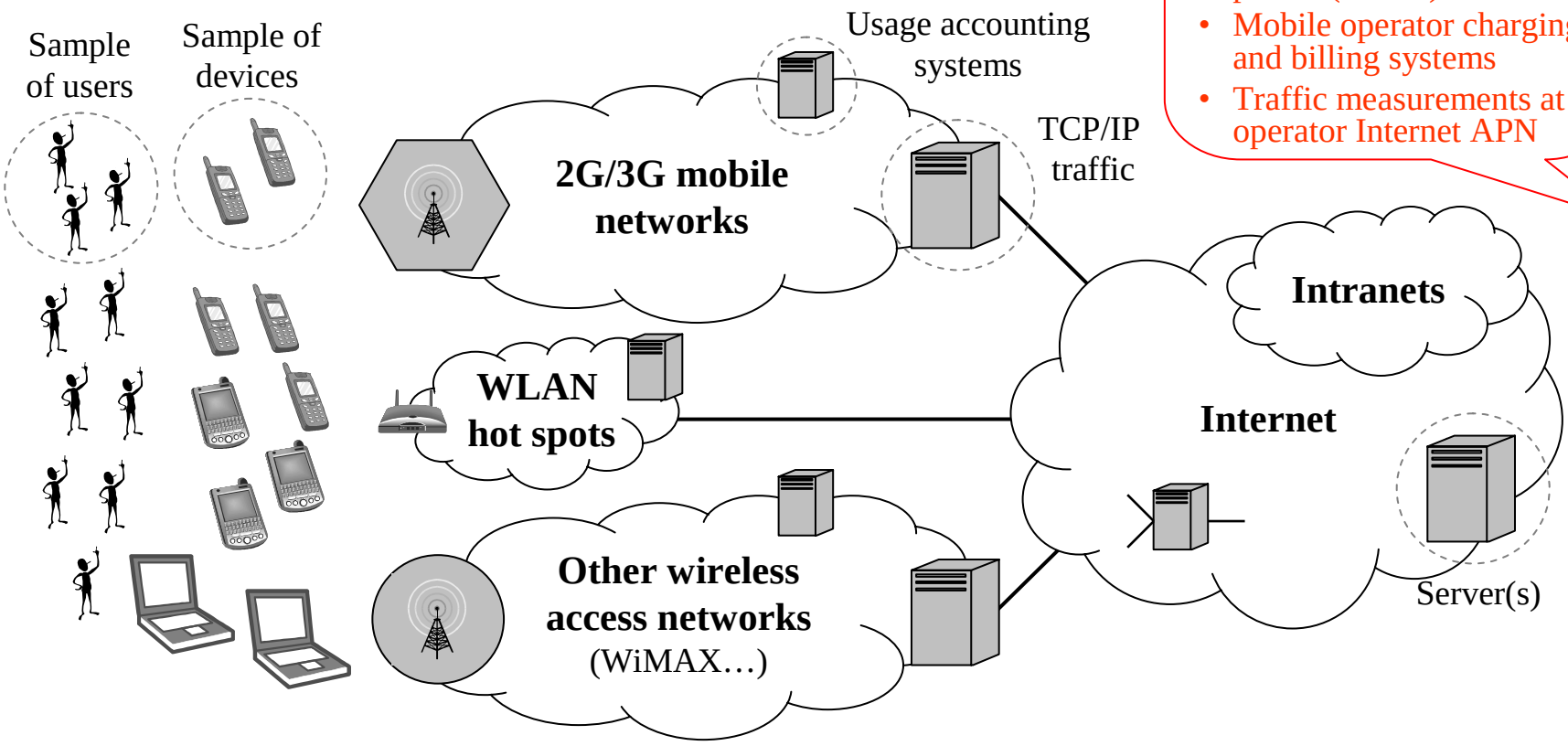
Antero Kivi

2.4.2007

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

- Mobile operator reporting system -based data collection
  (80-90% of Finnish mobile subscribers/terminals in fall 2005 and 2006)
  - Finnish mobile terminal base renewing rapidly, average age down 4 months (from 2,9 to 2,6 years)
  - Terminal features enabling data usage are spreading, 3G penetration up from 0,5% (2005) to 8% (2006)
  - Total mobile network packet data traffic increased almost 4x, consumer sub. traffic almost 5x
  - Only 3% unit (≈100 000) increase in number of weekly packet data users, growth in average traffic per active subscriber (>3x for consumer subs.) almost covers growth in total traffic volume
  - Lower price/MB ←→ more frequent and higher volume packet data usage
  - 3G capability ←→ more frequent and higher volume packet data usage, with all terminal types
  - Traffic predominantly to/from the Internet (Internet APN: 89% of all traffic)
  - PC traffic dominates handset traffic, data cards generate at least 35% of traffic
- TCP/IP traffic measurements
  (80-90% of Finnish mobile network packet data traffic on one week in fall 2005 and 2006)
  - Windows generates 70% of traffic in mobile networks → handset traffic profile largely hidden by Windows
  - At least 16% of traffic actually made with Symbian handsets, while Symbian devices act as GSM/UMTS terminals for 32% of traffic (handsets as modems)
  - Web dominates (>50%) mobile network traffic, P2P small (6%) but growing
  - Symbian traffic profile differs from Windows, share of email is higher (3x) and mobile P2P marginal (1/10)
  - Mobile operator sites (12%), information (9%) and entertainment (6%) significant browsing categories
  - In Symbian browsing mobile operator sites in a big (22%) and growing role

Agenda

- Operator Reporting System –Based Measurements
- TCP/IP Traffic Measurements
- APPENDIX

HELSINKI UNIVERSITY OF TECHNOLOGY
Networking Laboratory

Operator Reporting System –Based Measurements

Mobile Data Service Usage Measurements

Contents

Contents

Measurement description

- Data collected using mobile operators' charging-oriented reporting systems in fall 2005 and 2006
  - Ticket (CDR) and subscriber information systems of Finnish GSM/UMTS operators
  - Data primarily from 2 weeks or 1 month in Sep – Oct, 2005 and 2006
- About 80-90% of Finnish mobile subscribers/terminals included
  - Operators included in 2005 and 2006: 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 2005 data was available only from two operators

Contents

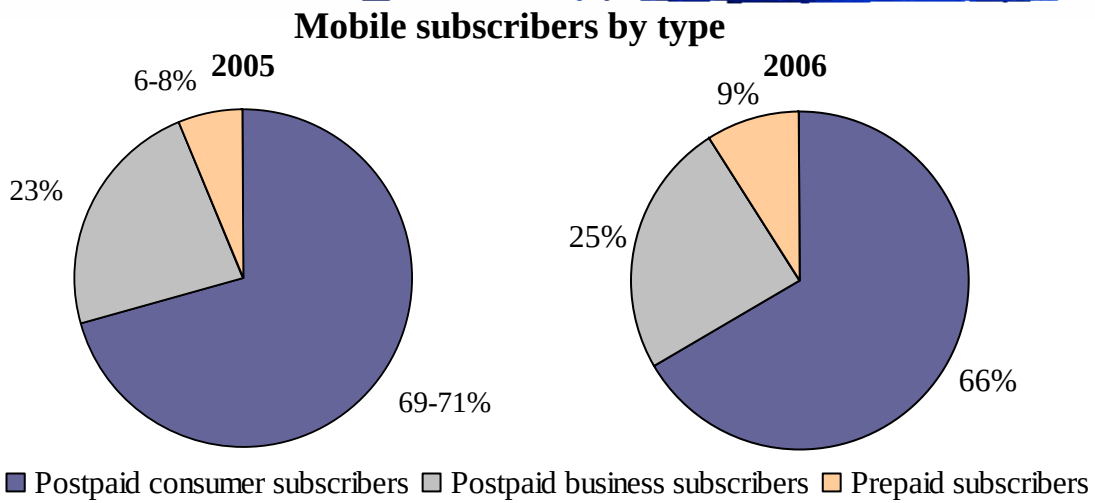
Description of source data

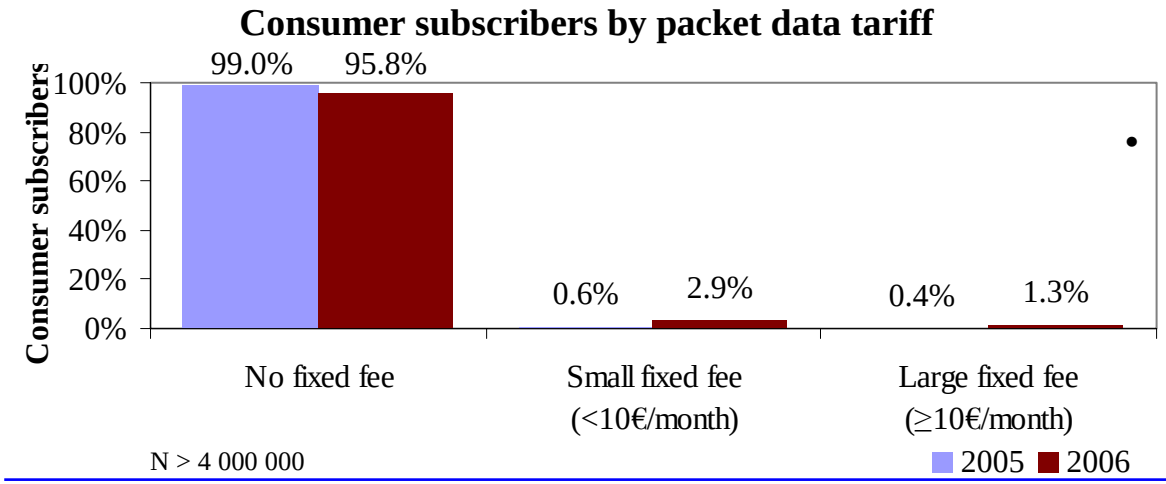
- *Active subscriber* is a subscriber that has generated packet data traffic during the studied week
- *Packet data traffic* (in subscriber context) includes all basic chargeable packet data traffic transfer by postpaid subscribers
  - Includes: basic packet data transfer
    Excludes: roaming, MMS, and other separately chargeable traffic
  - Some error due to differences in operator-specific data sets (2006)
  - Data collected in 2005 concerning subscribers comparably included ”basic packet data transfer” only

- See appendix A for more details on collected data and estimates on potential sources error

Operator reporting system data: Mobile subscriber base

Mobile subscribers by type of subscription





- Fixed fee data packets have become more popular…
  - Increase of 3 percentage points, i.e. about 100 000 more subscribers
  - Still only 4% of consumer subs. with a data packet, i.e. about 150 000 subscribers in Finland
- …resulting from major changes in offered packet data price schemes since Q1/2006
  - Introduction of various flat-rate alternatives
  - Related to the beginning of handset bundling in 4/2006
- Other remarks
  - Finland still >90% postpaid country
  - ¾ of postpaid subscribers are consumer subscribers
  - 5-10% of all consumer subscribers with a bundling contract

Consumer subscriber roaming

Consumer subscriber roaming on study week	2005	2006
Share of voice and/or SMS roamers	3 – 4%	3,6 %
Share of packet data roamers	0,1%	0,4%
Ratio of packet data roamers to voice roamers	2 – 6%	10%
Average traffic volume per packet data roaming consumer subscriber	0,4 – 0,8 MB / week	2,1 MB / week

N > 4 000 000

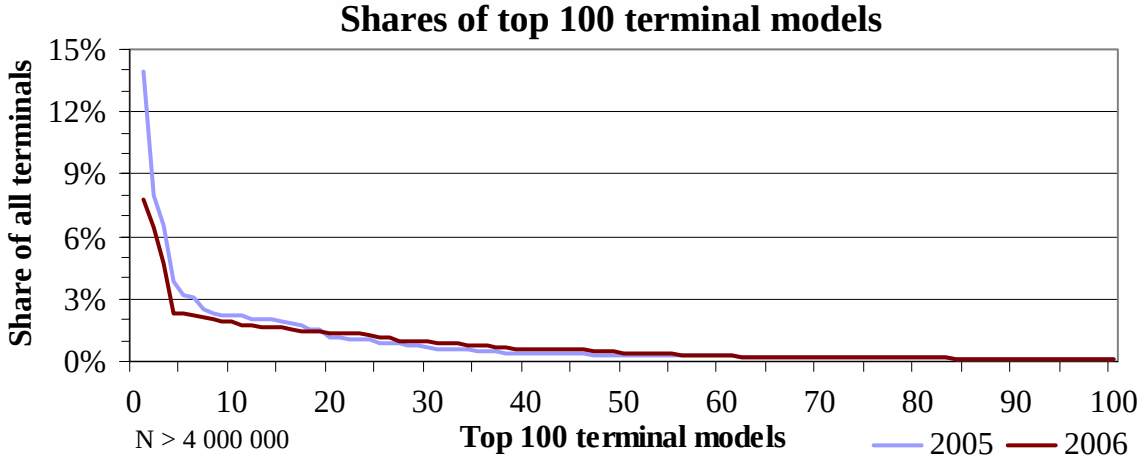
- 3-4% of all consumer subscribers use their mobile phone abroad every week
  - Made or received voice calls, sent SMSs
- Packet data roaming activity increased to correspond usage at home network
  - Consumer packet data usage at home network: 11% use weekly for avg. of 2,7 MB per packet data using sub.
- Some reliability issues with source data
  - Data from 2005 particularly heterogeneous

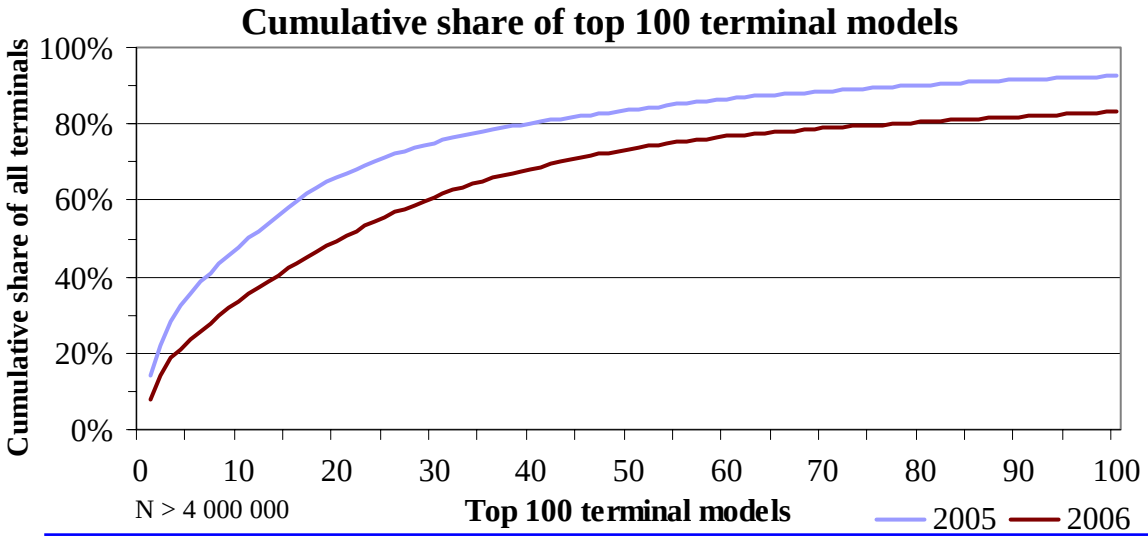
Contents

Description of source data

- *Terminals* include 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…)
  - Data on terminal features collected primarily from manufacturer web sites
  - Some error due to churn and differences in data sets
  - Some error due to unidentified terminals and terminal features
- *Active terminal* is a terminal that has generated packet data traffic during a studied week
- *Packet data traffic* (in terminal context) includes all mobile network packet data traffic by the terminals of all mobile subscribers (2006)
  - Includes: basic packet data transfer, roaming, MMS and other separately chargeable traffic
  - Some error due to differences in operator-specific data sets concerning included traffic (in 2006)
- See appendix B for more details on collected data and estimates on potential sources error

Mobile terminals by model

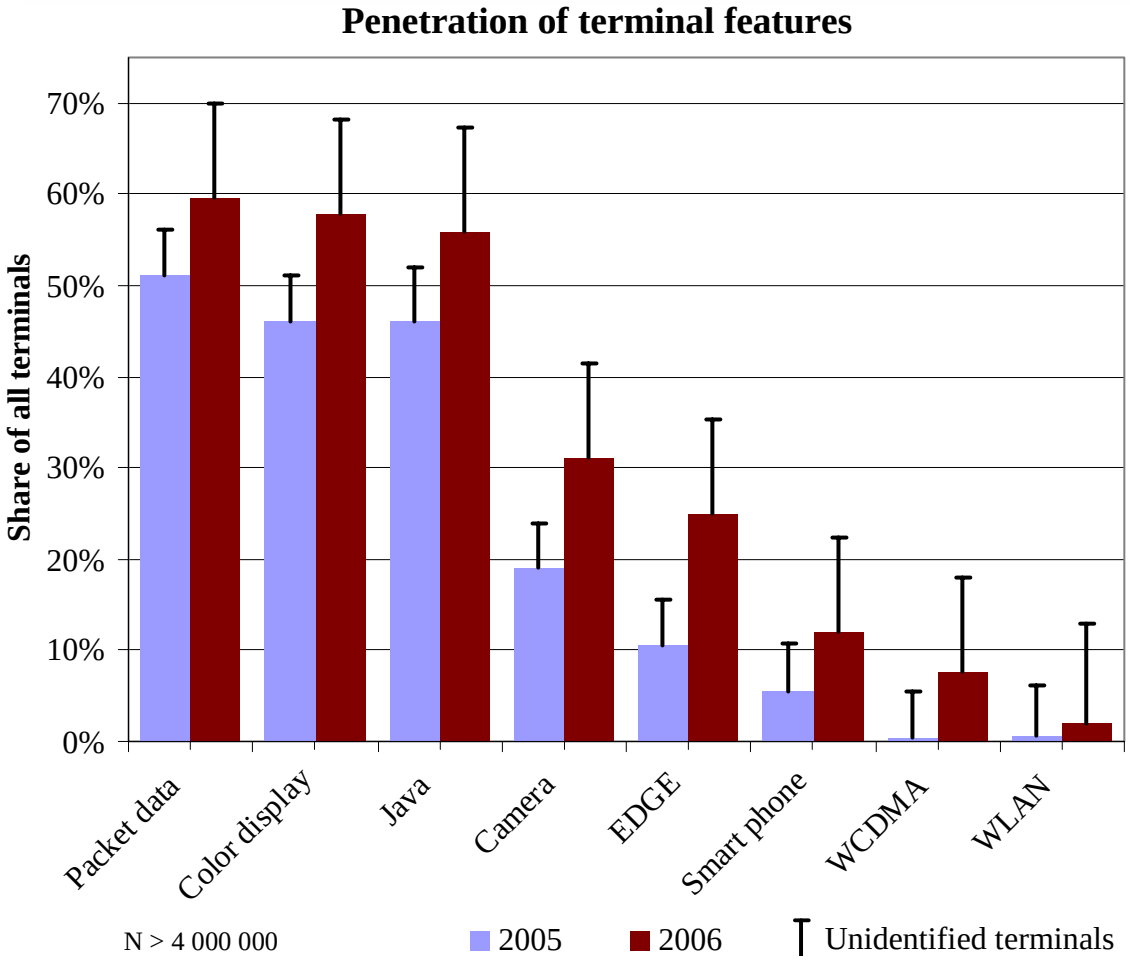




- Terminal base is less concentrated in 2006 as in 2005
  - Top 50: from 84% to 73%
    Top 100: from 93% to 83%
  - Broader handset offering?
  - Mixture of ”old” and “new” models cause this temporarily?
- Nokia 3310 is still the most popular terminal
  - From 14% (2005) to 8% (2006)
- Nokia N70 is the most popular ”high end” handset (ranked 4th)
  - First WCDMA terminal, camera phone, smart phone…
- Other remarks
  - Roughly 1000 different terminal models identified in total
  - First WLAN terminal ranked 37th
  - Unidentified terminals likely increases concentration, but not to 2005 level

Operator reporting system data: Mobile terminal installed base

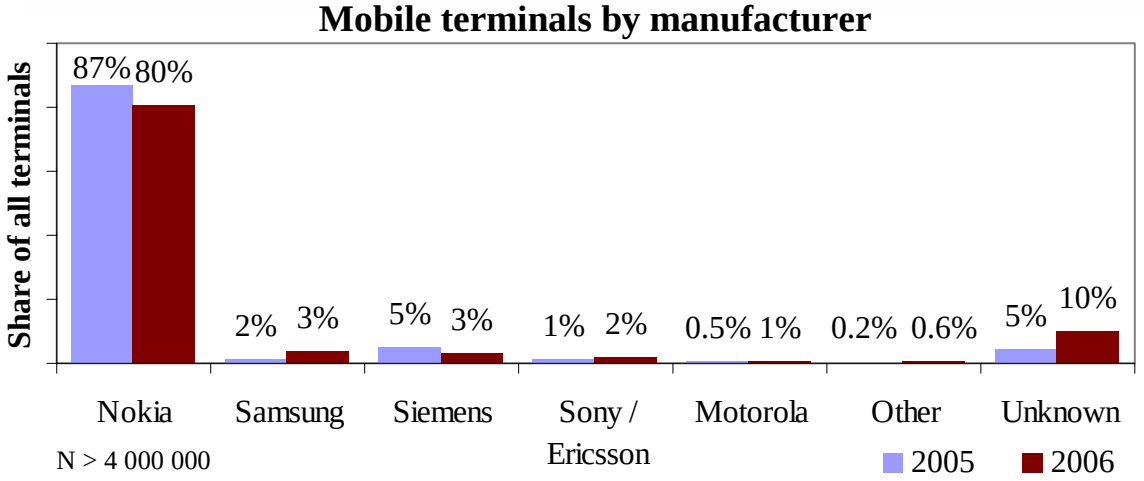
Mobile terminals by feature

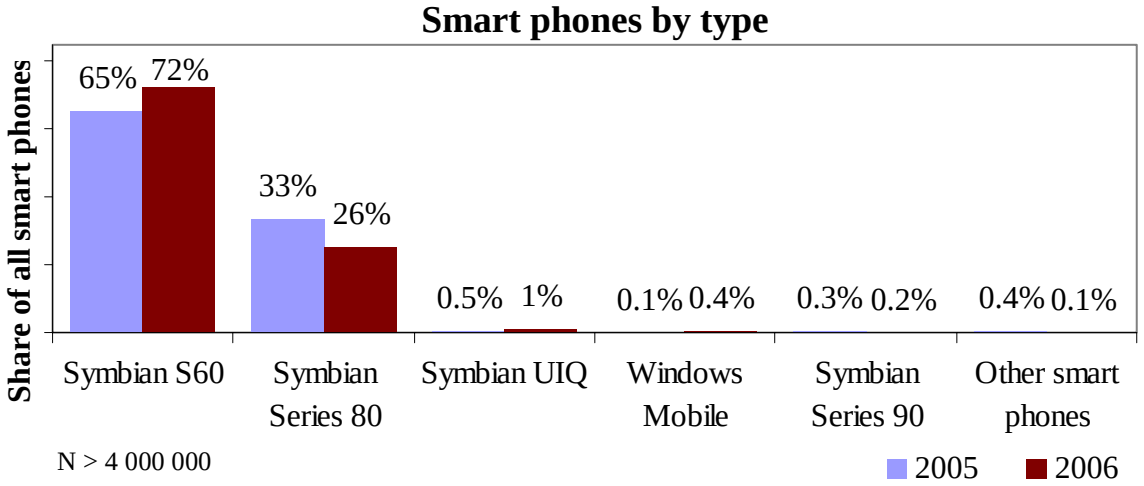


- Key features for packet data usage spreading
  - Packet data 51 % → 60 %
  - Java 46 % → 56 %
  - EDGE 11 % → 25 %
  - Smart phones 6 % → 12 %
  - WCDMA 0,5 % → 8 %
  - WLAN 0,7 % → 2 %
  - HSDPA 0 % → 0,1 %
- Unidentified terminals (T) somewhat increase the figures of all features
  - 10-11% in 2006, 5-6% in 2005
  - Unknown profile likely somewhat more advanced than identified terminal base
- Other remarks
  - Share of non-handset terminals up from 0,6% (2005) to 1,3% (2006)

Operator reporting system data: Mobile terminal installed base

Mobile terminals by manufacturer and smart phone type

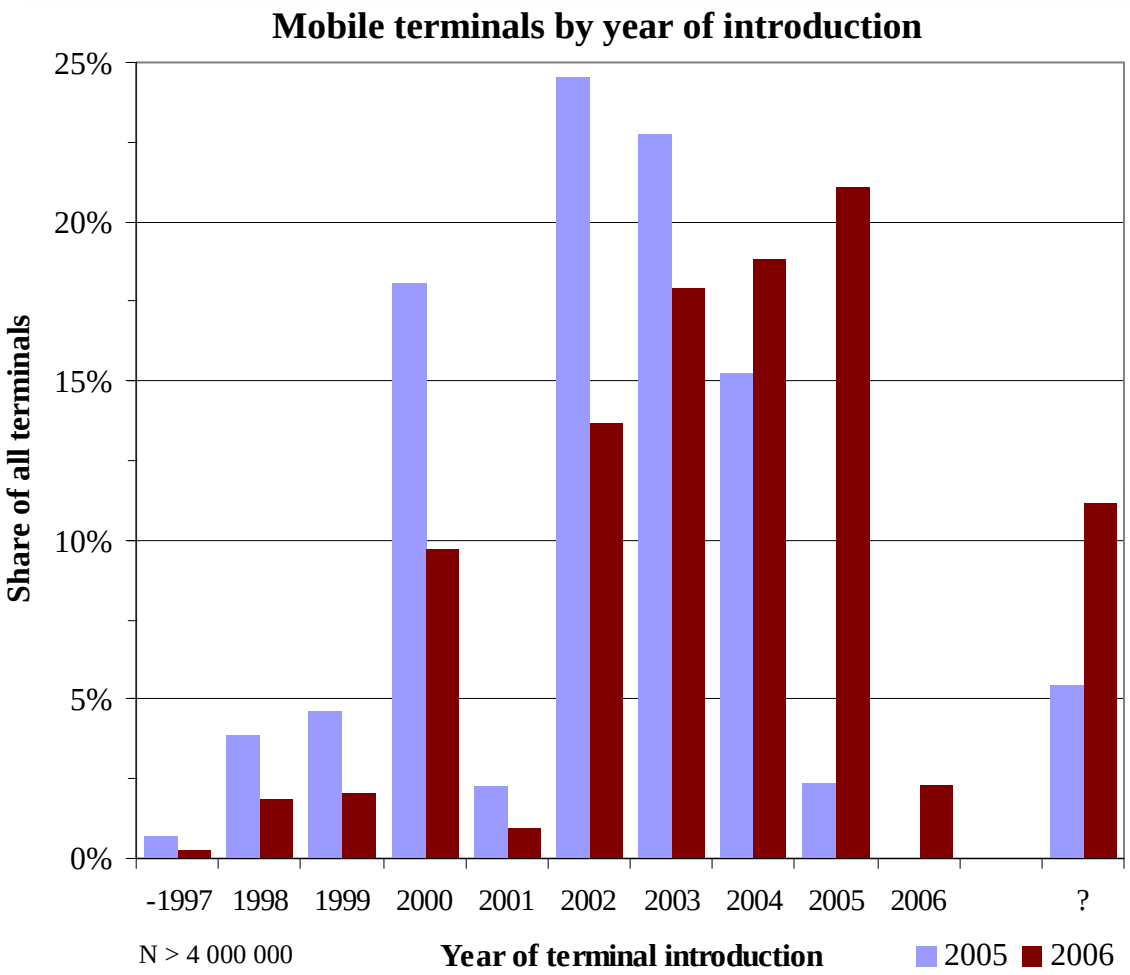




- Nokia's over 80% market share remarkable, but slightly decreasing
  - First non-Nokia ranked 36th
  - Samsung has taken the 2nd place
  - Sales of bundled 3G handsets by manufacturer reflect this development
- Nokia Symbian dominates smart phone market even clearer
  - Smart phone base is uniforming
    - S60 platform replacing Series 80 (Nokia communicators), and new communicators are based on S60
  - Other smart phone types seem to be marginal
- Smartphone shares not entirely reliable
  - Smart phones among unknown terminals could change shares of different smart phone types
  - Symbian terminals still the clear majority of smart phones

Operator reporting system data: Mobile terminal installed base

Mobile terminals by year of introduction

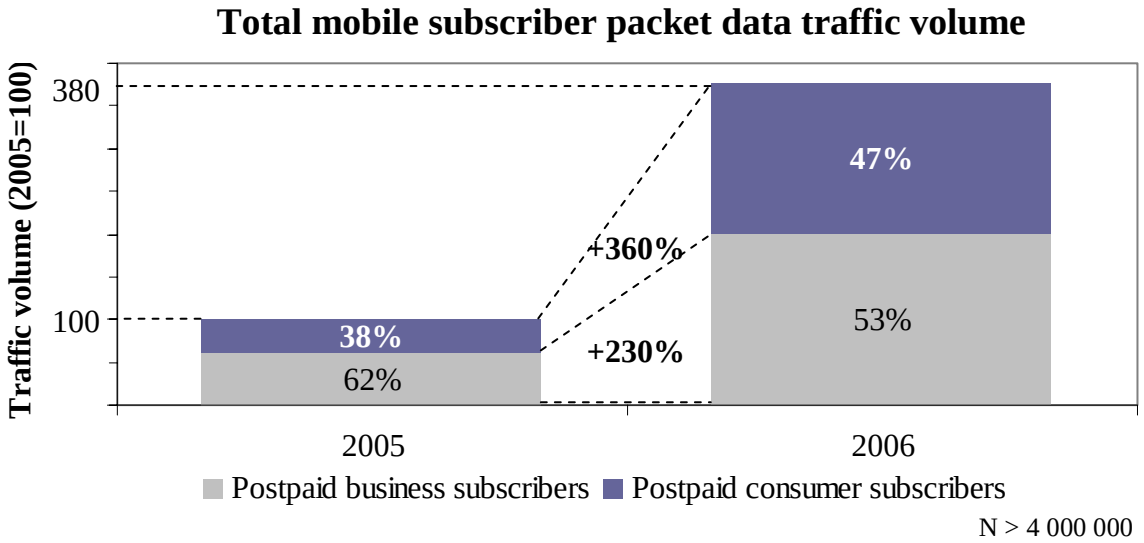


- Mobile terminal base renewed by more than one year in 2005-2006
  - Average “age” down from 2,9 (2005) to 2,6 (2006), i.e. by 4 months (measurement year – year of introduction)
  - Avg. year of intro. from 2002 to 2004
- Bell curve (product life cycle) broken by 2005 and 2001
  - Many terminals from 2005 (in 2006 data) due to changed market focus towards advanced handsets
  - Very few terminals from 2001
- Reliability issues
  - Year of introduction not well defined
    - Official or accidental introduction?
    - Delay from terminal introduction to start of sales not stable, depends on e.g. manufacturer and market
    - Data from manufacturer press releases, but also from the Internet
  - Considerable 11% of "Unknown", likely with somewhat newer profile than identified terminal base

Contents

- Measurement description
- Mobile subscriber base
  - Description of source data
  - Mobile subscribers by type of subscription
  - Consumer subscriber roaming
- Mobile terminal installed base
  - Description of source data
  - Mobile terminals by model
  - Mobile terminals by feature
  - Mobile terminals by manufacturer and smart phone type
  - Mobile terminals by year of introduction
- Mobile packet data traffic
  - Mobile subscriber packet data traffic
  - Mobile subscriber packet data traffic per subscriber
  - Consumer subscriber packet data traffic by pricing
  - Packet data traffic by terminal type
  - Packet data traffic by service
- Summary and conclusions
  - Summary
  - Conclusions

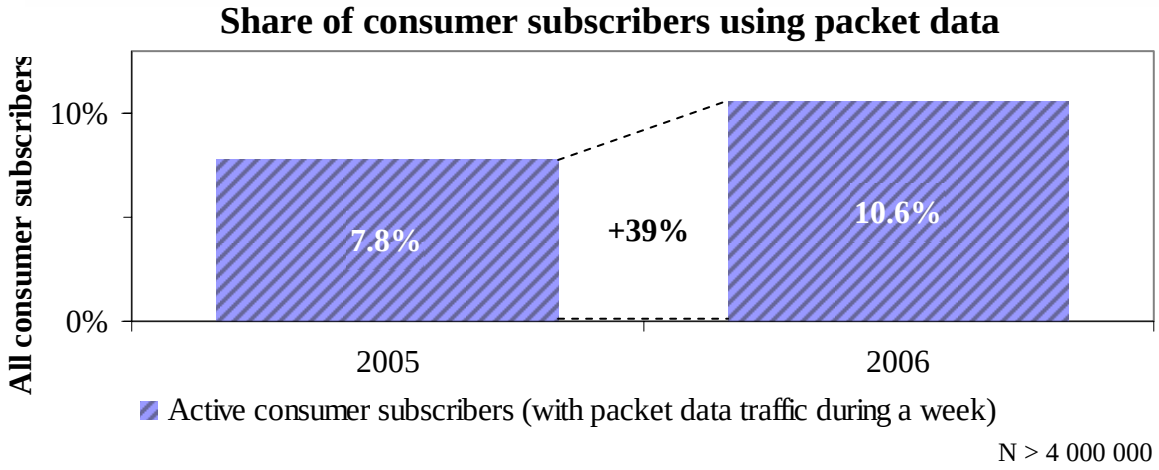
Mobile subscriber packet data traffic

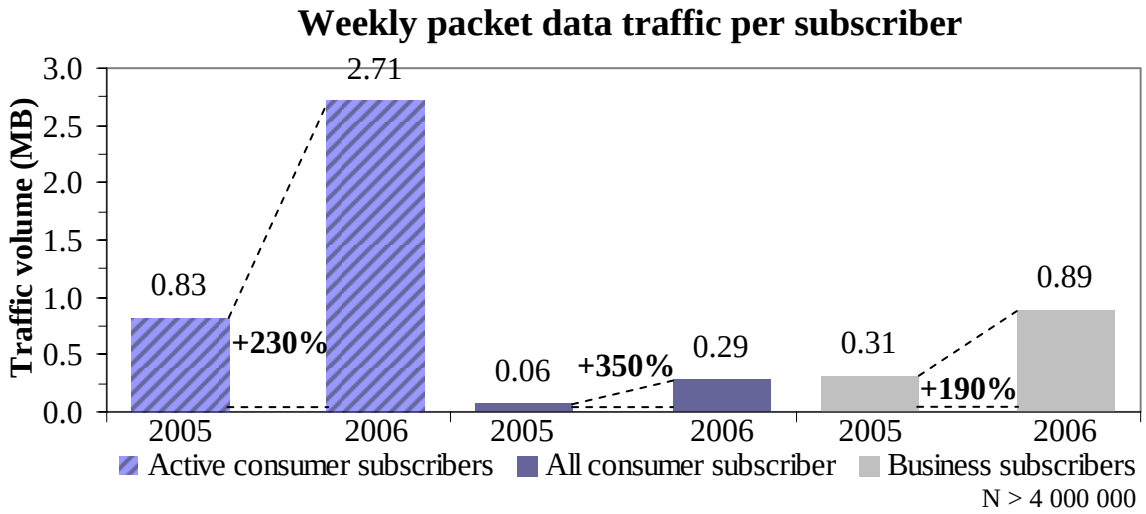


- Mobile subscriber packet data usage grown almost 4x
  - Statistics Finland: total mobile network data traffic 34 000 GB in 2005 (650 GB/week), which corresponds to the traffic volumes measured in 2005
- Consumer subscriber packet data usage up almost 5x
  - More users?
  - More usage per user?

Operator reporting system data: Mobile packet data traffic

Mobile subscriber packet data traffic per subscriber



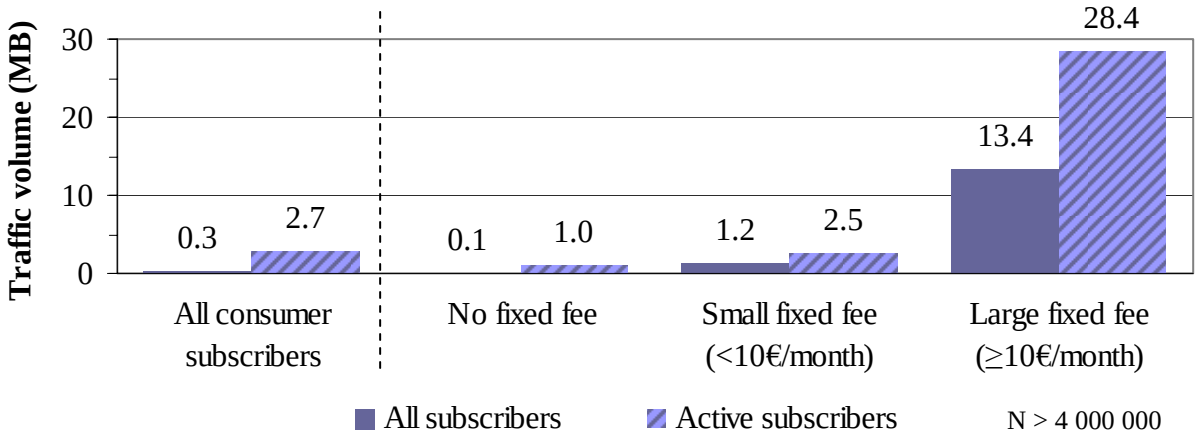


- Only 3 percentage point increase in share of weekly users
  - 39% more (≈100 000) packet data using consumer subscribers
- High growth results from increased average traffic per subscriber
  - Traffic per active consumer subscriber >3x
  - Business subs. still generate 3x as much traffic per subscriber
- Why is average usage growing?
  - Lower price/MB?
  - More capable terminals and networks (3G, HSDPA)?
  - More laptop usage?
  - More data services?
  - New data-intensive services?
  - Better usability?
  - More marketing?
  - …?

Operator reporting system data: Mobile packet data traffic

Consumer subscriber packet data traffic by pricing

Weekly packet data traffic volume per subscriber (2006)



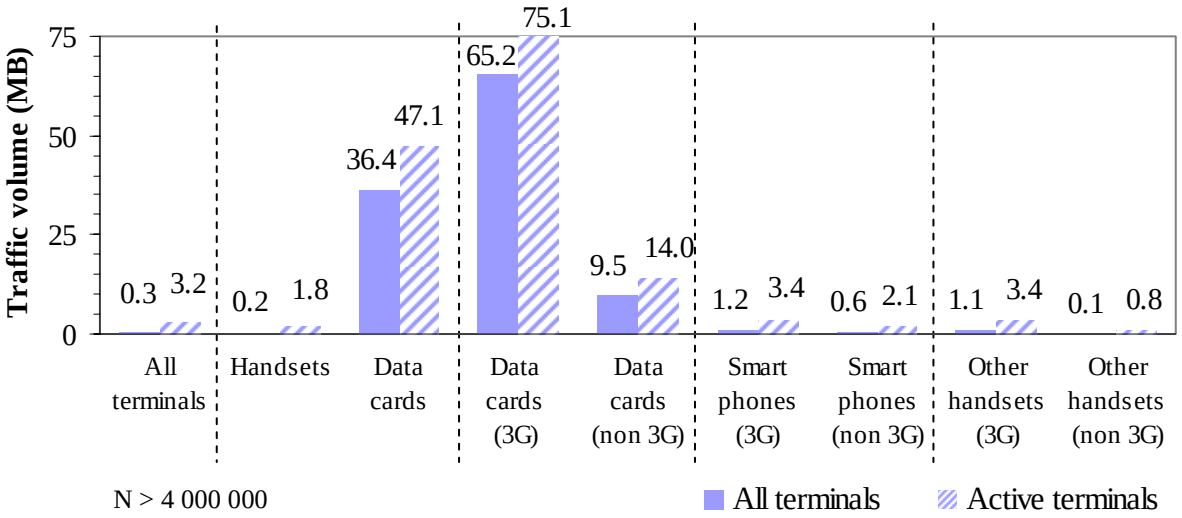
Share of consumer subscribers using packet data (2006)

All consumer subscribers	No fixed fee	Small fixed fee (<10€/month)	Large fixed fee (≥10€/month)
11%	9%	48%	47%

- Fixed fee packets very actively used
  - ≈50% use weekly
  - >70% of all traffic
- Lower price/MB ←→ higher usage
  - More frequent and voluminous usage
  - Holds also for almost all individual tariffs, except the highest (premium)

Packet data traffic by terminal type

Weekly packet data traffic per terminal (2006)



Share of terminals using packet data (2006)

All terminals	Handsets	Data cards	Data cards (3G)	Data cards (non 3G)	Smart phones (3G)	Smart phones (non 3G)	Other handsets (3G)	Other handsets (non 3G)
11%	11%	77%	87%	68%	36%	30%	34%	7%

- 3G capability ←→ higher usage for all types of terminals
  - >5x traffic per data card
  - ≈2x traffic per smart phone
  - >4x traffic per “other” handset
- No difference between 3G smart phones and other 3G handsets
  - Other 3G handsets also quite ”smart” (Nokia Series 40, SonyEricsson Java platform…)
- Other remarks
  - Data cards actively used for data
    - Data cards account for 35% of all packet data traffic
    - >25x as much traffic per terminal than for handsets
  - Non-3G smart phones more used than other non-3G handsets
    - Smart phones also have other features correlating with packet data usage (e.g. large display, advanced browser, Bluetooth)
  - 14% of total traffic volume by unidentified terminals

Packet data traffic by service

- No actual data on service usage besides packet data traffic volumes
- Traffic predominantly to/from the Internet
  - Internet APN 89% of total packet data traffic volume (90% in 2005)
  - WAP APN ≈7% of total packet data traffic volume
  - MMS APN <1% of total packet data traffic volume
  - Corporate APNs ≈3% of total packet data traffic volume
- PC traffic dominates handset traffic
  - Data cards generate at least 35% of traffic
  - Windows OS actually creates 70% of all Internet APN traffic (see 2nd part of the presentation)
- Effect of new data services not known
  - 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

Contents

- Measurement description
- Mobile subscriber base
  - Description of source data
  - Mobile subscribers by type of subscription
  - Consumer subscriber roaming
- Mobile terminal installed base
  - Description of source data
  - Mobile terminals by model
  - Mobile terminals by feature
  - Mobile terminals by manufacturer and smart phone type
  - Mobile terminals by year of introduction
- Mobile packet data traffic
  - Mobile subscriber packet data traffic
  - Mobile subscriber packet data traffic per subscriber
  - Consumer subscriber packet data traffic by pricing
  - Packet data traffic by terminal type
  - Packet data traffic by service
- Summary and conclusions
  - Summary
  - Conclusions

Summary

- Data from mobile operators' CDR and subscriber information systems with 80-90% (> 4 000 000) of Finnish mobile subscribers/terminals in fall 2005 and 2006

- Finnish mobile terminal base renewing rapidly, average age down 4 months (from 2,9 to 2,6 years)
- Terminal features enabling data usage are spreading, 3G penetration up from 0,5% (2005) to 8% (2006)
- Nokia handsets (>80%) and Nokia Symbian smart phones (>99% of smart phones) dominate the terminal markets

- Finland still a >90% postpaid country, ¾ of postpaid subscribers are consumers
- >4% of consumer subscribers have some monthly fixed fee tariff on packet data usage (2005: 1%)

- Total mobile network packet data traffic increased almost 4x, consumer sub. traffic almost 5x
- Only 3% unit (≈100 000) increase in number of weekly packet data users
- Avg. traffic per active subscriber almost covers traffic volume growth, >3x for consumer subs.

- Lower price/MB ←→ more frequent and higher volume packet data usage
- 3G capability ←→ more frequent and higher volume packet data usage, regardless of terminal type (data card, handset, smart phone)
- Traffic predominantly to/from the Internet (Internet APN: 89% of all traffic)
- PC traffic dominates handset traffic, data cards generate at least 35% of traffic

Conclusions

- Finnish mobile market has some peculiarities
  - Dominance of Nokia and Nokia/Symbian
  - High share of postpaid subscribers
- Mobile terminal base has improved due to changed market focus towards advanced handsets
- Consumer masses have not started using mobile data services, despite improved 3G penetration
- Existing users have acquired more capable terminals and price/MB has decreased
- Critical mass for data service adoption is not yet achieved in Finland
  - Improvements in terminal base nevertheless lay the enabling conditions for mass market adoption in the (near?) future

HELSINKI UNIVERSITY OF TECHNOLOGY
Networking Laboratory

TCP/IP Traffic Measurements

Mobile Data Service Usage Measurements

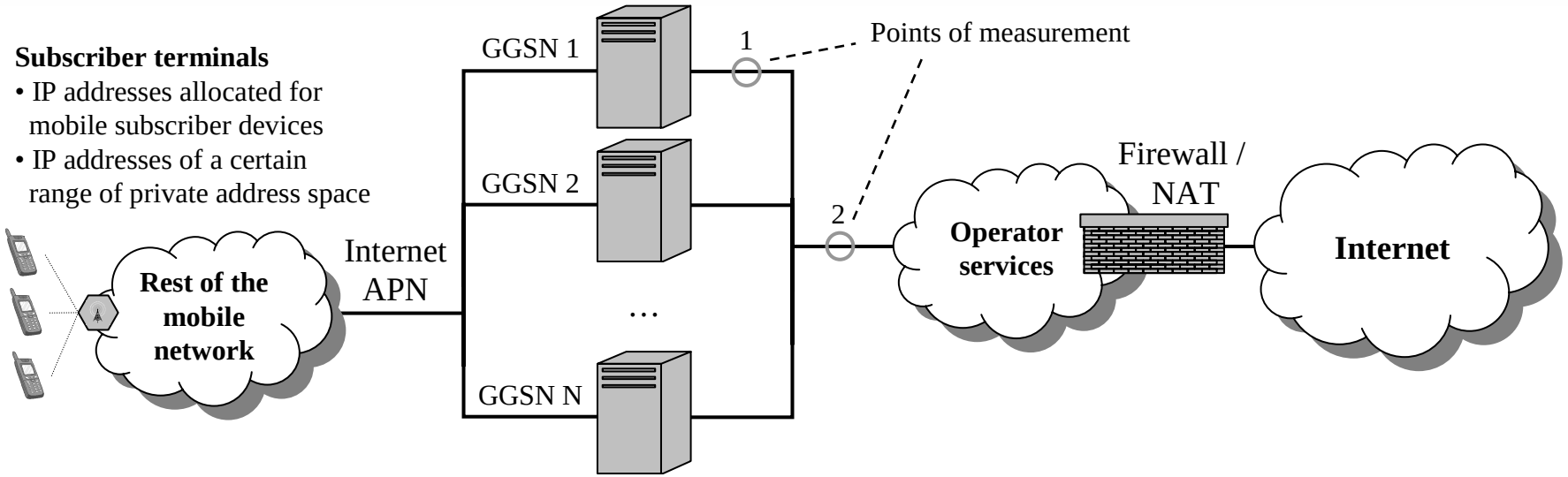
Contents

Contents

Measurement scope

- Packet data traffic at mobile operator Internet APN measured for a week in fall 2005 and 2006
  - TCP, UDP and IP protocol headers captured
    - In 2006 also headers of other protocols on top of IP
  - ≈90% of all packet data traffic (all APNs) goes via Internet APN
  - Measurements for two weeks in Sep – Oct 2006, one week in 2005
    - Measurements not completely simultaneous
- About 80-90% of Finnish mobile network packet data traffic included
  - Operators included Sonera, Elisa (+Kolumbus), and DNA (2006)
    - 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)

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 on one side of traffic, all other IP addresses considered servers
  - Problem: public IP addresses for mobiles → client-server roles sometimes reversed

Identification of terminal operating systems

- Terminal operating system (OS) identified using *TCP fingerprinting*
  - 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 smartphone OSs can be identified with reasonable accuracy

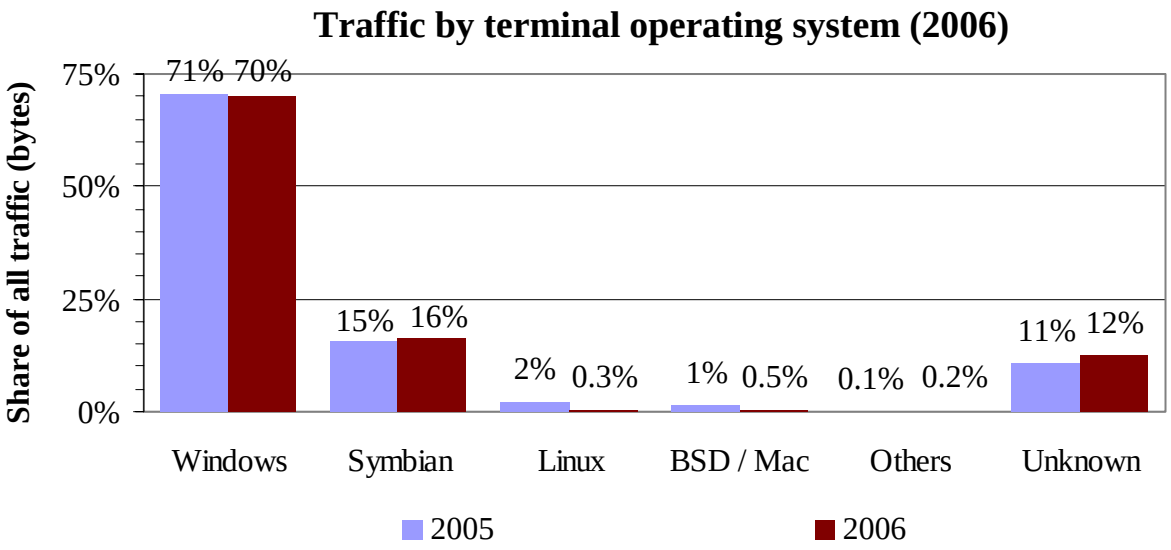
- Operating system identification process includes some possible bias
  - Only mobile terminal OSs identified
  - OS identification based on uplink TCP traffic only (57% of flows, 23% of bytes)
    - OS of uplink TCP flows identified → that OS resides at a certain IP address at a certain time frame
    - Downlink TCP flows, and all UDP flows accounted for different OSs based on this information
  - What is the effect of the 43% of flows not used in OS identification?
    - OS identified correctly after the first uplink TCP flow for as long as the terminal has the same IP address
    - OS identification of TCP based application protocols (e.g. web, email) is more reliable

Contents

General traffic patterns

- Traffic volume grown about 4x between the measurements in 2005 and 2006
  - Accurate absolute growth figures not available from this measurement, as only 2 operators measured in 2005
  - Statistics Finland: total mobile network data traffic 34 000 GB in 2005 (650 GB/week)
- Traffic dominantly TCP
  - 2006: 88% of byte volume
  - 2005: 84% of byte volume
- Traffic dominantly towards the mobile terminals (downlink)
  - 2006: 73% of byte volume
  - 2005: 84% of byte volume
- Other protocols <2% of total traffic volume
  - Mainly IPSec ESP traffic (VPN), >80% of other protocols
  - Excluded from the rest of the analyses

Traffic by mobile terminal operating system



- Windows originates 70% of traffic in mobile network
  - Data cards, GPRS modems, handsets as modems via Bluetooth/cable
  - A few PCs create more traffic than many mobiles → OS identification necessary to uncover handset traffic
  - Windows Mobile, Windows CE, and Pocket PC traffic in “Others” category
- At least 16% of traffic actually made with Symbian handsets
  - 32% of traffic with Symbian device as the GSM/UMTS network terminal (CDR data) → 4–16% of this traffic from modem usage
- Unknown 12% of traffic problematic
  - All other handsets, possibly additional laptop and Symbian traffic
  - Telematics, machine-to-machine (M2M) comm., alarm terminals, remote cameras…?
  - Do intelligent modems / GPRS modules, VPN, or access network elements (SGSN/GGSN, firewall) alter the TCP fingerprint?

Contents

TCP/IP traffic: Packet data traffic by application protocol

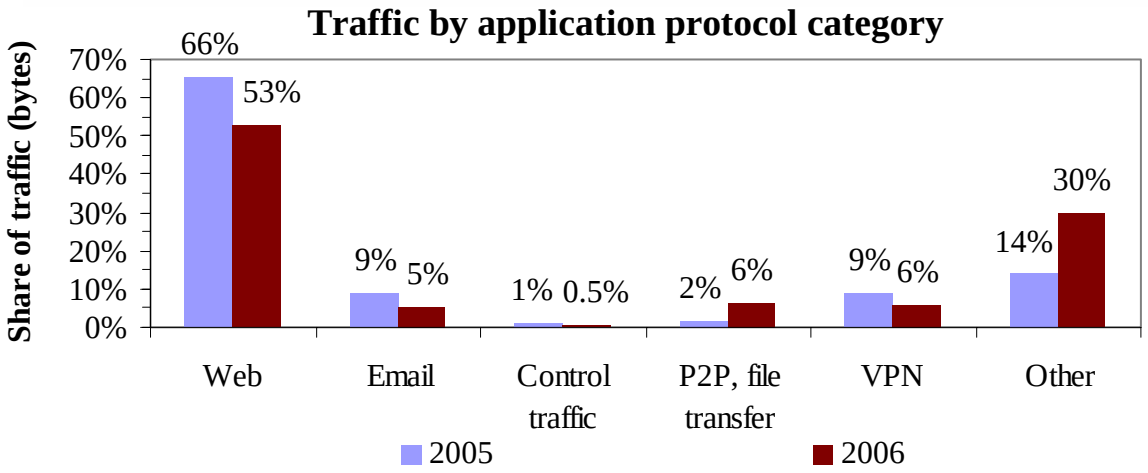
Most popular application protocols

Rank	TCP port	Share of TCP traffic (bytes)	UDP port	Share of UDP traffic (bytes)
1.	80	53.6%	2746	14.0%
2.	443	6.0%	10000	13.2%
3.	4662	3.0%	4500	10.2%
4.	110	2.6%	370	8.9%
5.	143	1.3%	500	4.1%
6.	119	1.2%	53	3.7%
7.	25	1.1%	32555	1.4%
8.	7777	1.1%	5004	1.4%
9.	6881	1.0%	434	1.2%
10.	7171	0.7%	49000	0.8%
	Others	28.4%	Others	41.2%

- Application protocols identified with server-side TCP/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 apps. (e.g. P2P, streaming…)
    - Subscriber terminals also as servers as public IP addresses used → client ports observed
- TCP traffic mainly web and email
  - Web: HTTP (80), HTTPS (443)
  - Email: POP3 (110), IMAP (143), SMTP (25)
  - News: NNTP (119)
  - P2P: eDonkey (4662), Limeware (7777), BitTorrent (6881)
  - Unknown: 7171
- UDP traffic mainly VPN
  - VPN: CheckPoint UDP Encapsulation (2746), NDMP / Cisco IPsec VPN (10000), IPsec / NAT-Traversal (4500), ISAKMP / IKE (500)
  - Others: F-Secure updates / BackWeb (370), Mobile IP agent (434), DNS (53)
  - Unknown: 5004, 32555, 49000

TCP/IP traffic: Packet data traffic by application protocol

Traffic by application protocol category

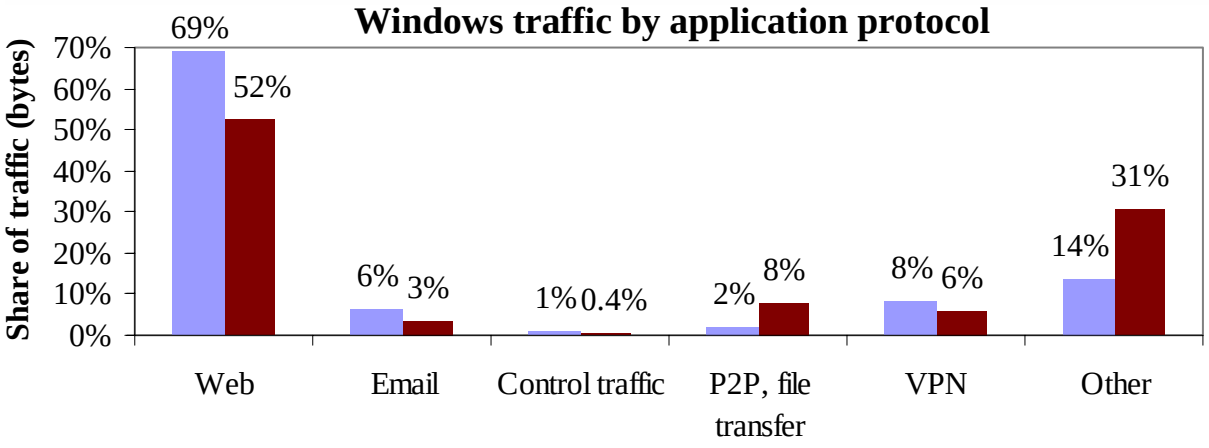


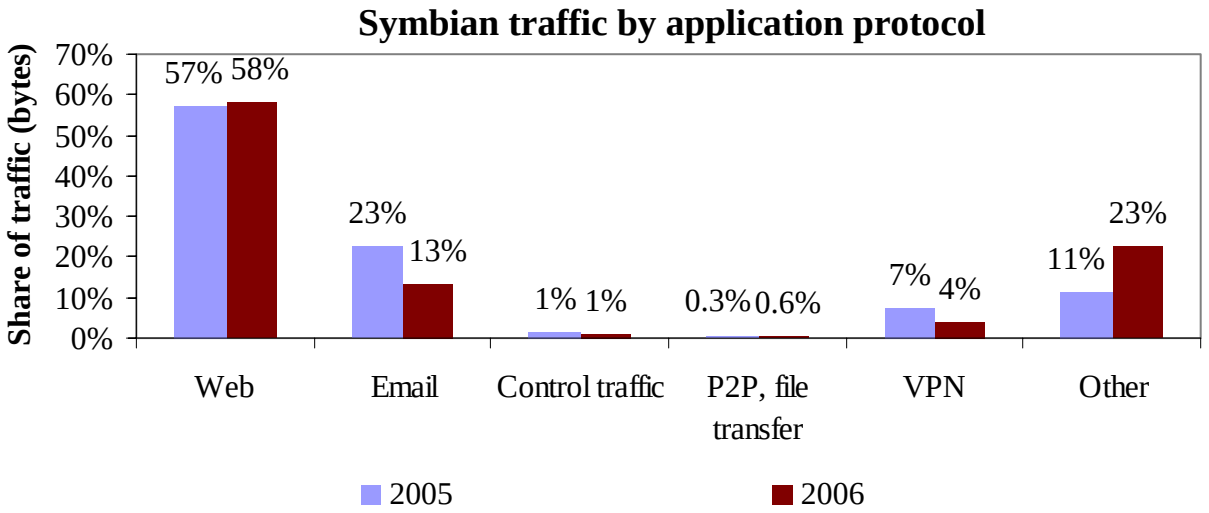
Application protocol category	Transport protocol ports included*	
Web	TCP	80, 443, 8080
Email	TCP	110, 143, 25, 993, 995
Control traffic	UDP	53, 5060, 123
P2P, file transfer	TCP	4662, 7777, 6881, 1412, 20, 9999, 6346, 411, 6882, 412
VPN	TCP	10000, 500
	UDP	2746, 10000, 4500, 500, 1194
Others	TCP	119, 7171, 11469, 554, 1863, 12001, 1352, 3000, 1935, 32459, 22, 1750
	UDP	370, 32555, 5004

* TCP/UDP ports with at least 0,5% of total bytes in category

- Port numbers grouped into 6 application protocol categories
  - >30% uncategorized protocols → categories simplify but are ambiguous
- Web traffic dominates with >50% traffic share
  - Includes video streaming, possibly P2P
- ”Other” category with most growth
  - P2P and streaming becoming more mainstream also in mobile network?
  - Also client ports, self-initiated Windows traffic, client ports, malware
- P2P traffic increasing
  - More P2P likely in Web and ”Other”
  - Still much smaller than in fixed Internet
- Other remarks
  - Relative shares of web, email, and VPN traffic are decreasing
    - All growing in absolute, but less than other applications
    - VPN & Web likely include more email

Traffic by application protocol category and OS



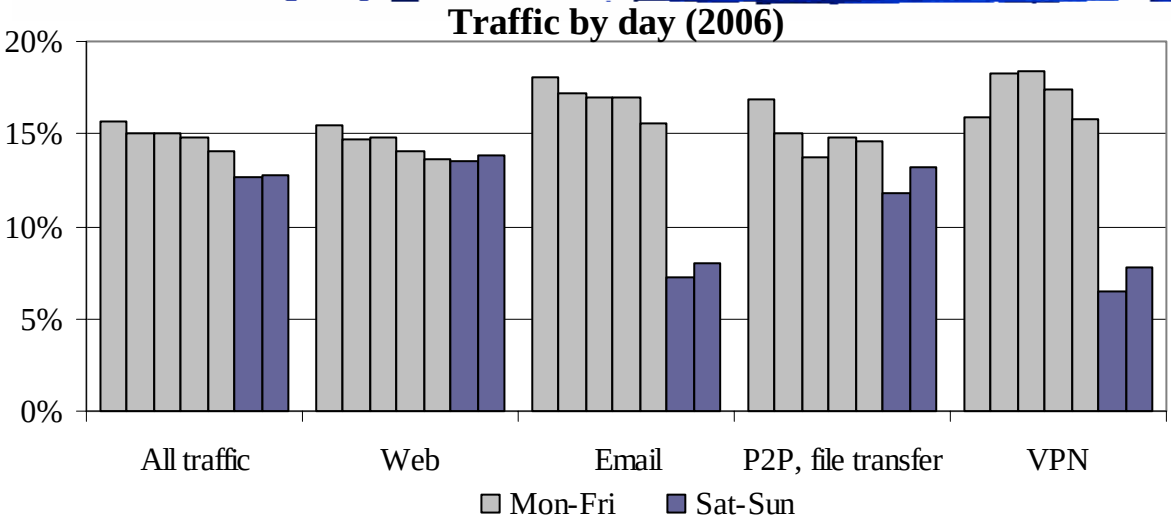


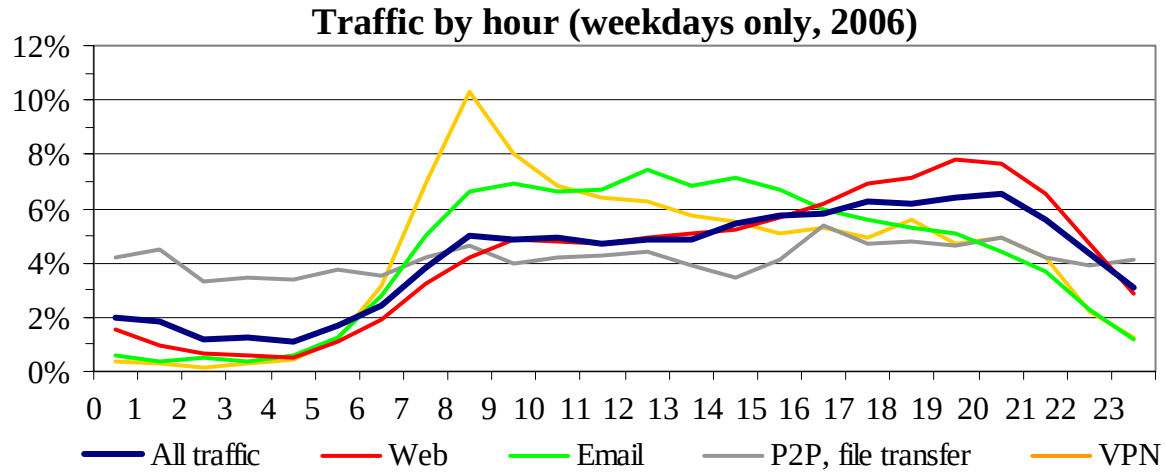
- Windows profile as the profile for all traffic
  - Imposes itself with 70% share of traffic
- Symbian profile differs from Windows in some ways
  - Email share 3x higher
  - P2P share only 1/10
- Web and “Other” driving traffic growth on Symbian
  - Decreasing email traffic still significant with 13% share
- Other remarks
  - VPN also used on Symbian
    - Nokia Mobile VPN Client, related to Check Point
  - Share of Symbian P2P traffic very low (0,6%)

Contents

TCP/IP traffic: Packet data traffic by application and time

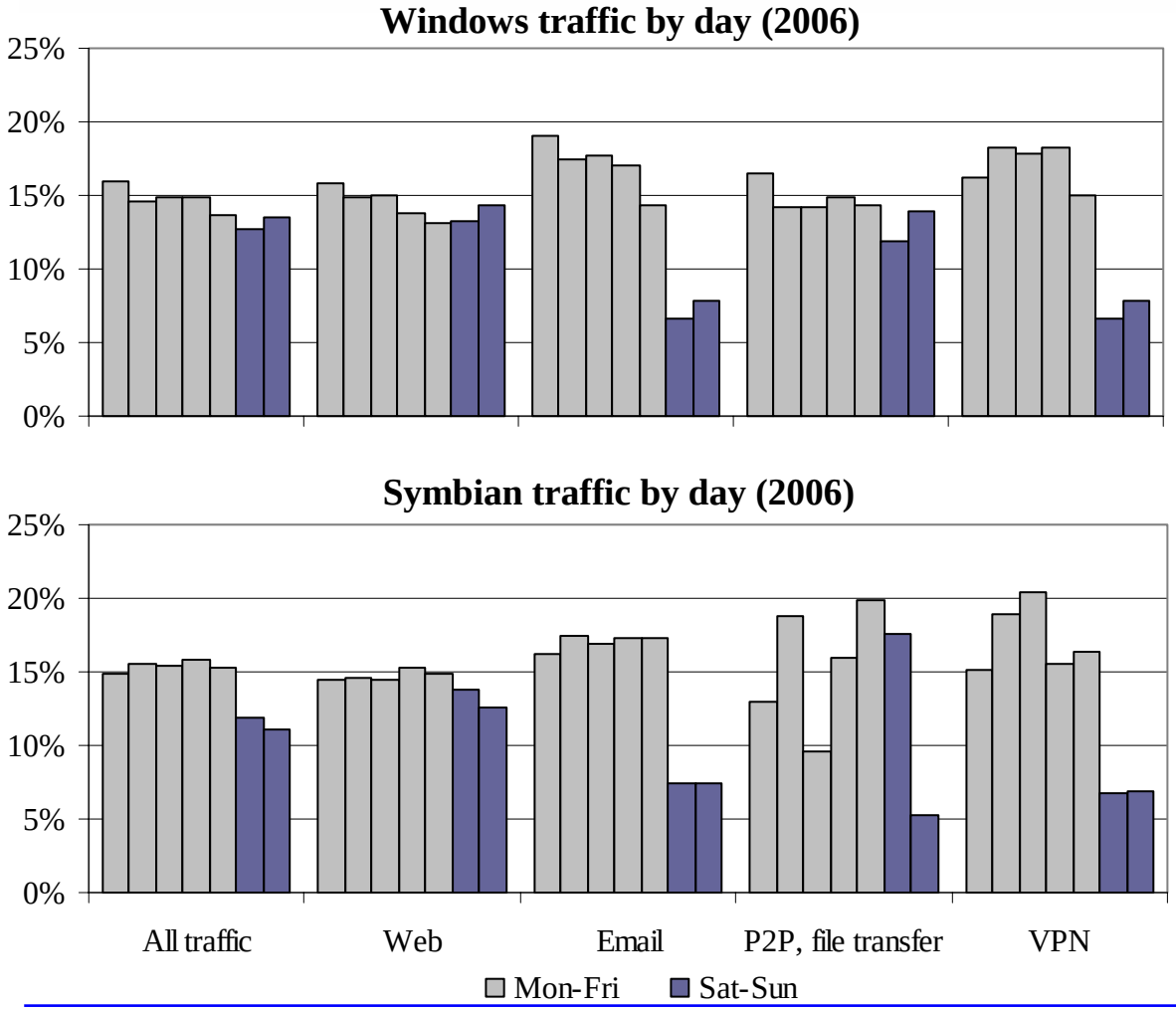
Traffic by day and hour





- Monday most active day, peak hour at 8–9PM
  - 16% of weekly traffic on Mondays
  - 6.5% of daily traffic at 8–9PM
- Business-oriented email and VPN less used on weekends
- Web is free-time oriented
  - Almost equal usage during weekdays and weekend
  - Most usage in the evening on weekdays
- Other remarks
  - VPN peaks at 8–9AM on weekdays
  - Email used quite evenly during office hours
  - P2P traffic present all day

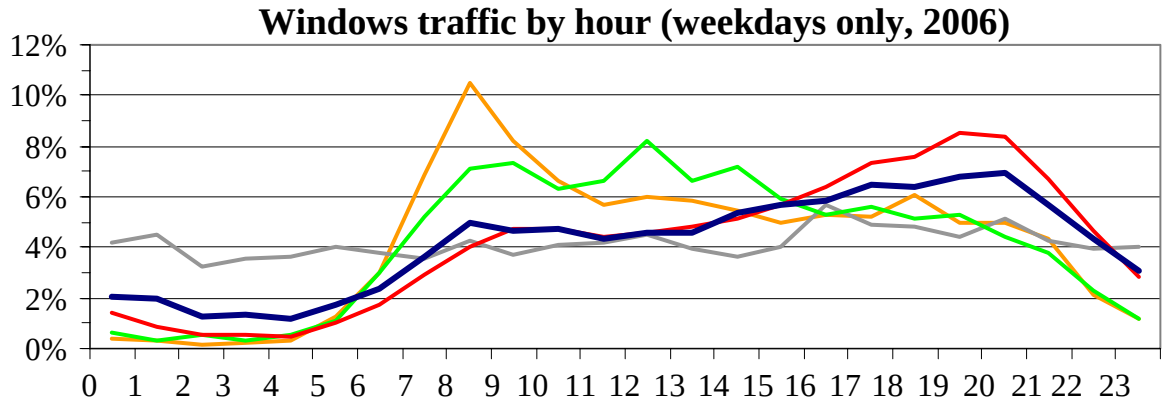
Traffic by day and operating system

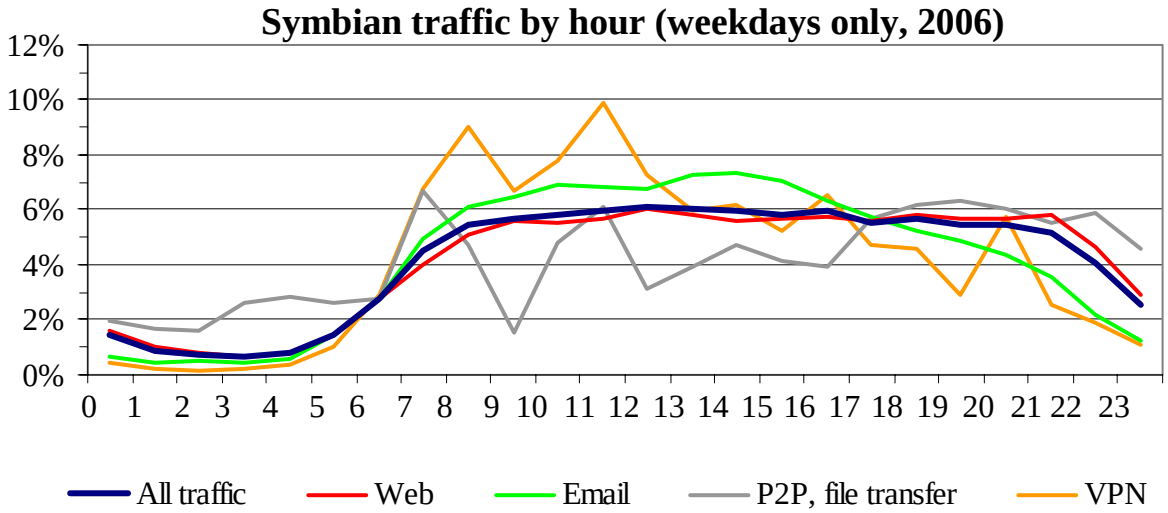


- Windows profile again as the profile for all traffic
- Symbian profile quite similar to Windows profile
  - Symbian P2P not representative due to negligible P2P volume (0,6% of traffic)

TCP/IP traffic: Packet data traffic by application and time

Traffic by hour and operating system





- Windows profile again as the profile for all traffic
- Symbian usage quite even from 8AM to 9 PM
  - Peak hour 12AM–1PM
  - No increase in web usage in the evening
  - VPN traffic has a 2nd peak before noon
  - P2P traffic again error prone due to small volume

Contents

Most popular web sites

Rank*	Domain name of site	Share of web traffic volume	Share of web site visits**
1	akamai.net	4.2%	1.5%
2	irc-galleria.net	2.1%	2.9%
3	statistik-gallup.net	0.4%	4.4%
4	basefarm.net	1.7%	2.2%
5	mtv3.fi	1.6%	2.3%
6	google.com	1.7%	1.9%
7	sanomawsoy.fi	0.6%	1.7%
8	doubleclick.net	0.5%	1.5%
9	akamaitechnologies.com	1.7%	0.2%
10	nebula.fi	0.9%	0.9%
11	youtube.com	1.4%	0.3%
12	yahoo.com	0.6%	1.0%
13	iltalehti.fi	0.8%	0.8%
14	yle.fi	0.7%	0.7%
15	seksitreffit.fi	0.5%	0.8%
	Other identified domains	51.1%	49.0%
	Unknown addresses	19.2%	18.8%
	Private addresses	10.2%	9.2%

* Ranked by the domain's combined share of traffic volume and site visits
** Share of TCP flows to/from the domain
# of web site visits <= # of flows <= files downloaded from site

- Server IP addresses of all TCP flows with ports 80, 8080, 8000, 8888, and 443 included
  - Might include P2P or malware traffic as well (traffic to e.g. port 80 goes through firewalls)
  - → 225000 web server IP addresses
  - → 220000 domain / sub domain names
    - First PTR record listed taken into account
  - → 41000 domain names
- Web traffic not very concentrated to few domains
  - 21% of traffic in top 10, 47% in top 100
- Unknown addresses about 19% of traffic
  - Server (web or other) IP addresses for which no reverse DNS entry was available
- Private addresses 10% of traffic volume
  - Web/WAP servers/proxies in operator network?

TCP/IP traffic: Web protocol traffic patterns

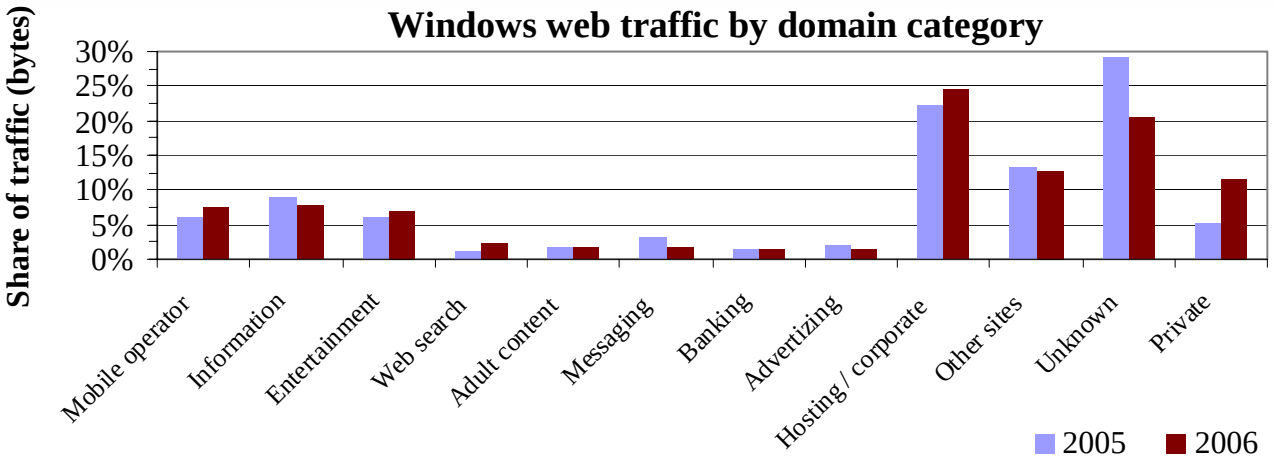
Most popular web sites by category

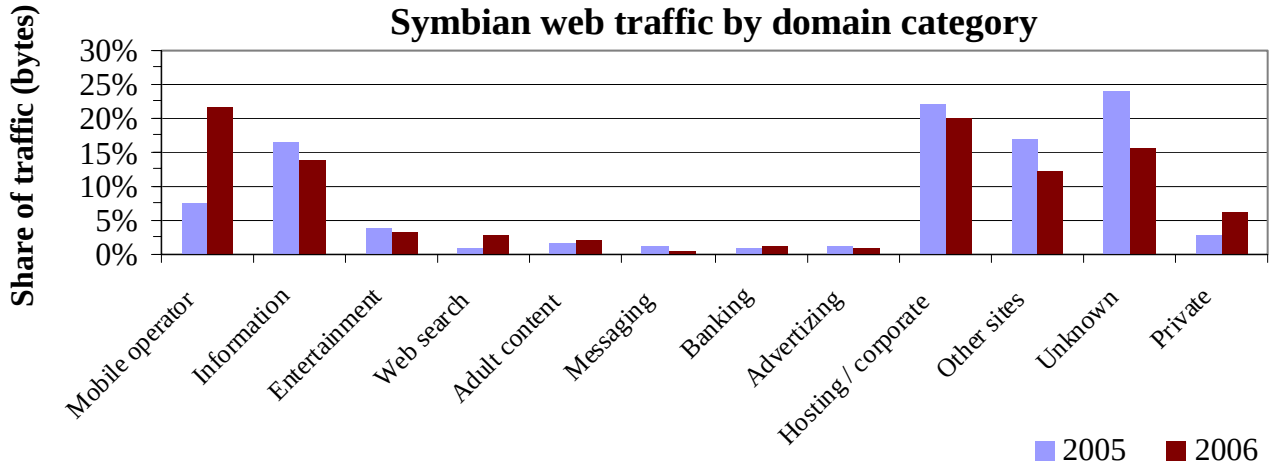
Rank*	Site category	Major domains included**	Share of web traffic volume	Share of web site visits
1.	Mobile operator site	-	11.8%	9.9%
2.	Information	mtv3.fi, sanomawsoy.fi, iltalehti.fi, yle.fi, sanoma.fi, helsinginsanomat.fi	8.8%	11.8%
3.	Entertainment	irc-galleria.net, youtube.com, telkku.com, veikkaus.fi	5.9%	5.7%
4.	Web search	google.com, yahoo.com	2.5%	3.0%
5.	Adult content	seksitreffit.fi, sihteeriopisto.net	1.8%	1.7%
6.	Messaging	luukku.com, hotmail.com, msn.com, passport.net, gmail.com	1.4%	2.9%
7.	Banking	op.fi, sampo.fi, nordea.fi, eQonline.fi, huoneistokeskus.fi, alandsbanken.fi, aktia.fi, osuuspankki.fi	1.4%	1.2%
8.	Advertising	doubleclick.net, advertising.com, adtech.de, theonlinetrader.com, tradedoubler.com	1.2%	3.4%
	Hosting / corporate site	akamai.net, statistik-gallup.net, basefarm.net	23.3%	22.2%
	Other sites	-	12.5%	10.2%
	Unknown	-	19.2%	18.8%
	Private	-	10.2%	9.2%

* Ranked by the category's total share of traffic volume
** Sites with at least 10% of the total bytes or flows of the category

- Domain names grouped into 12 categories, despite many potential sources of error
  - About 40% share of unknown, private, and uncategorized sites
  - Domain name resolving method gives domains of hosting service providers and not the hosted services
  - Categorization based on domain name, not sub domain name
  - Categorization itself is subjective, ambiguous, and error prone
  - Overlapping categories (e.g. Information and Entertainment, Web search and Messaging)
  - Possible non-web traffic
- Mobile operator sites (12%), information (9%) and entertainment (6%) significant categories
- Lots of traffic to “infrastructure” hosts not intentionally connected by users
  - Advertising (banners, pop up windows)
  - Load sharing (e.g. akamai.net)
  - Web site analytics (e.g. statistik-gallup.net)

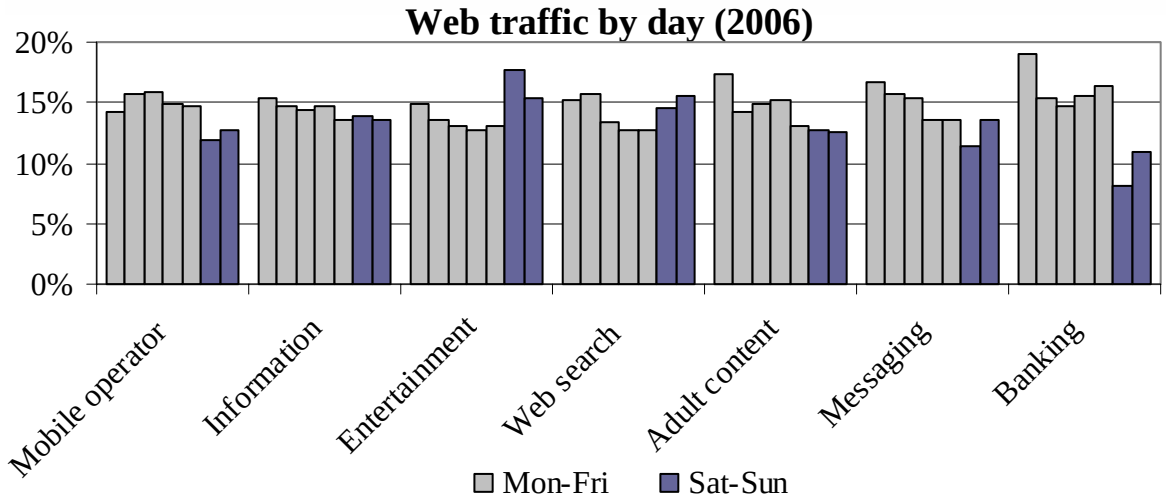
Most popular web sites by category and operating system

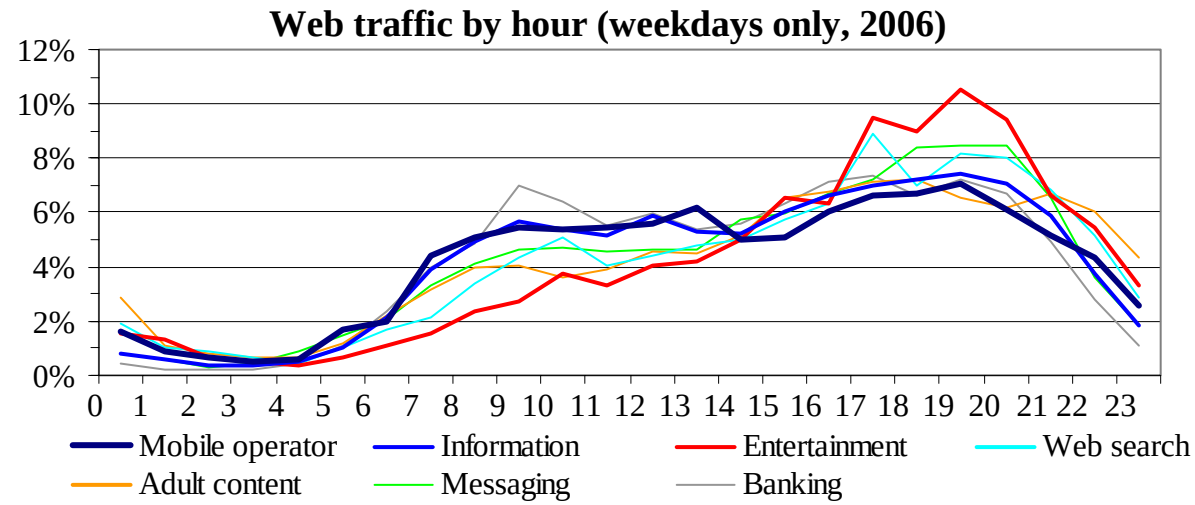




- Mobile operator sites in a bigger, and growing role for Symbian
  - 22% of all Symbian browsing traffic
  - More ”basic” consumer users accessing operator services instead of Internet sites in 2006?
- Share of Information high for Symbian
  - Lots of mobile-adapted content (e.g. mtv3, YLE, HS)
- Lots of uncertainty
  - Very high share of the last 4 non-specific categories
  - Higher share of these for Windows (70%) could imply presence of non-web protocols

Most popular web sites by category, day and hour





- Entertainment and Web search free time oriented
  - More traffic on weekends and in the evening...
  - … as was for web traffic in general
- Banking most active on weekdays, peak at 9–10AM
  - Banking only 1,4% of all web traffic

Contents

Summary

- 80-90% of Finnish mobile network packet data traffic captured at three mobile operators' Internet APN for a week in fall 2005 and 2006

- Windows originates 70% of traffic in mobile networks → handset traffic profile largely hidden by Windows traffic
- Web dominates (>50%) mobile network traffic, P2P small (6%) but growing
- Most traffic generated on Mondays (16% of weekly traffic), peak-hour at 8-9PM (6.5% of daily traffic)
- Mobile operator sites (12%), information (9%) and entertainment (6%) significant browsing categories

- At least 16% of traffic actually made with Symbian handsets, while Symbian devices act as GSM/UMTS terminals for 32% of traffic (handsets as modems)
- Symbian traffic profile differs from Windows, share of email is higher (3x) and mobile P2P traffic marginal (1/10)
- Mobile operator sites in a big (22%) and growing role in Symbian browsing, "information" sites also actively accessed

Conclusions

- Symbian profile differs from general traffic profile in many ways
  - Separating terminal operating system is essential for understanding handset-based mobile service usage from traffic measurements
- Consumer-oriented usage is growing faster than business usage
  - Some P2P traffic has emerged, while the relative share of email and VPN is decreasing
- Mobile operator portal usage share increasing
  - Because (some) consumer subscribers have started using mobile data?
  - Could easily usable operator portals compete with Internet as average skill level of users drops when other user segments start adopting mobile data?

HELSINKI UNIVERSITY OF TECHNOLOGY
Networking Laboratory

APPENDIX

Mobile Data Service Usage Measurements

APPENDIX A

Description of source data: subscribers

- *Packet data traffic* includes all basic chargeable packet data traffic transfer by postpaid subscribers
  - Includes: basic packet data transfer
    Excludes: roaming, MMS, and other separately chargeable traffic
  - Error due to differences in operator-specific data sets (2006)
    1. Includes: basic packet data transfer
       Excludes: roaming, MMS and other separately chargeable traffic
    2. Includes: basic packet data transfer, roaming, MMS and other separately chargeable traffic
       → share of extra other separately chargeable traffic (e.g. mobile TV streaming) unknown
       → share of extra MMS traffic <0,3% of all traffic, unknown contribution to active users
       → share of extra roaming traffic <0,1% of all traffic, and <1% of active users
    3. Includes: basic packet data transfer
       Excludes: roaming, MMS and other separately chargeable traffic
  - Data collected in 2005 concerning subscribers comparably included ”basic packet data transfer” only

APPENDIX B

Description of source data: terminals

- *Terminals* include all terminals of all mobile subscribers observed at the network during the measurement week
  - Data sets from each operator in 2005
    1. All terminals observed at the network in week 34, no particular transactions nor operator subscription required
    2. All postpaid/prepaid subscribers' terminals with made voice calls / sent SMSs in September
    3. Top 100 postpaid/prepaid subscribers' terminals with chargeable transactions (phone call, SMS, other) in September
  - Data sets from each operator in 2006
    1. All postpaid/prepaid subscribers' terminals observed at the network on weeks 37/39, no particular transactions required
    2. All postpaid subscribers' terminals with chargeable transactions (voice calls, SMSs, packet/circuit –switched data traffic) in weeks 37/39
    3. Top 150 terminals (with chargeable transactions) and top 100 data generating terminals of postpaid and prepaid subscribers in September
  - Error due to churn and other differences in data sets
    - Churn during longer measurements: <1% in 2006, <3% in 2005 (Numpac: 39200 numbers ported in Sep 2006, 115 000 in Sep 2005)
    - Missing prepaid subscribers (2006 only): <5% , who supposedly have less advanced handsets than postpaid subs.
    - Max. 2,5% excess in measured terminal base due to foreign roamers and emergence call readiness (2005 only)
  - Error due to unidentified terminals and terminal features
    - 9,5% (2006) and 4,5% (2005) of terminals were unidentified → somewhat more advanced terminals than identified terminal base in general
      - TAC codes not identified: Manufacturers don't deliver TAC–model data to TAC allocating organizations in real time → no data for most recent terminals
      - Terminal models outside top 100 / top 150 models: most recent features not evenly represented among top 100
    - 0,5% -1,5% of identified terminals without some specific information on terminal features
- *Packet data traffic* includes all mobile network packet data traffic by mobile subscribers (2006)
  - Includes: basic packet data transfer, roaming, MMS and other separately chargeable traffic
  - Error due to differences in operator-specific data sets concerning included traffic (2006 only)
    1. Includes: basic packet data transfer, MMS and other separately chargeable traffic. Excludes: roaming
       → share of missing roaming traffic 2%, contribution to active users <2%
    2. Includes: basic packet data transfer and roaming traffic of postpaid subscribers.
       Excludes: MMS and other separately chargeable traffic of postpaid subscribers, and any traffic of prepaid subscribers
       → share of missing prepaid subscriber traffic unknown, likely <1% of traffic
       → share of missing MMS traffic <0,1% of all traffic, unknown contribution to active users
       → share of missing separately chargeable traffic unknown, likely negligible
    3. Includes: basic packet data transfer, roaming, MMS and other separately chargeable traffic

Further information

- Publications on the topic
  - A. Kivi, *Measuring Mobile User Behavior and Service Usage: Methods, Measurement Points, and Future Outlook*, to be published at 6th Global Mobility Roundtable, 1-2 June 2007, Los Angeles, California, U.S., 2007.
  - A. Kivi, *Mobile Internet Usage Measurements - Case Finland*, Master's thesis, Helsinki University of Technology, 2006.
- COIN project web site
  - http://www.netlab.tkk.fi/tutkimus/coin/
- Contact antero.kivi(at)tkk.fi