mobile business

# *Lecture 9*

## Mobile Devices


[Source: Nokia]

**Mobile Business I (WS 2016/17)**

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- Introduction
- Categorisation of Mobile Devices
- Components of Mobile Devices
  - Accumulators
  - Processors, Memory, and Storage
  - Display
  - Means for I/O

# Mobile Terminal vs. Mobile Device

- A *Mobile Device* is a small, handheld computing device.

- *Mobile Terminal* emphasises the fact that the mobile device represents the end of a communications link or the edge node of a communications network.

# Device Manufacturers and Brands

(including some historic ones)

- Alcatel
- Apple
- Audiovox
- Benefon
- BenQ Mobile
- Blackberry
- Bosch
- Ericsson
- Google
- HTC
- Huawei
- LG Electronics
- Microsoft
- Motorola
- NEC
- Nokia
- Panasonic


- Philips
- Sagem
- Samsung
- Sendo
- Siemens
- Sony
- TCL Communication
- Telepong
- Telit
- Telme
- Toshiba
- Trium
- Windhorst
- Xelibri
- Yulong
- ZTE

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# Worldwide Mobile Phone Sales to End Users by Vendor Q1-2016 vs. Q1-2005

| Company | 1Q16 units | 1Q156Market Share (%) | 1Q05 units | 1Q05 Market |
|---|---|---|---|---|
| Samsung | 81,187 | ***23.2*** | 24,479.8 | ***13.5*** |
| Apple | 51,630 | ***14.8*** | - | |
| Huawei | 33,002 | ***7.2*** | - | - |
| Oppo | 16,113 | ***4.6*** | - | |
| Xiaomi | 15,048 | ***4.3*** | | |
| LG Electronics (former LG) | ➲ others | | 11,464.2 | ***6.3*** |
| Lenovo*/Motorola | | | 30,143.3 | ***16.7*** |
| Huawei | | | ➲ others | |
| TCL Communication | | | | |
| ZTE | | | | |
| BenQ Mobile | | | 10,209.5 | ***5.7*** |
| Sony Mobile Com. | | | 9,905.8 | ***5.5*** |
| Others | 156,413 | ***44.8*** | 39,829.5 | ***21.9*** |
| **TOTAL** | **349,251** | **100.0** | **180,992.2** | **100.0** |

Based on [Gartner2016] and [Gartner2006]

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# Worldwide Mobile Phone Sales to End Users by Vendor Q1-2016 vs. Q1-2015

In 1.000 Units

| Company | 1Q16 Units | 1Q16 Market Share (%) | 1Q15 Units | 1Q15 Market Share (%) |
|---|---|---|---|---|
| Samsung | 81,186.9 | ***23.2*** | 81,122.8 | ***24.1*** |
| Apple | 51,629.5 | ***14.8*** | 60,177.2 | ***17.9*** |
| Huawei | 28,861.0 | ***8.3*** | 18,111.1 | ***5.4*** |
| Oppo | 16,112.6 | ***4.6*** | 6,585.1 | ***2.0*** |
| Xiaomi | 15,048.0 | ***4.3*** | 14,740.2 | ***4.4*** |
| Others | 156,413.4 | ***44.8*** | 155,561.4 | ***46.3*** |
| **Total** | **349,251.4** | **100.0** | **336,297.8** | **100.0** |

Based on [Gartner2016]

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# Worldwide Mobile Phone Sales to End Users by Vendor 2012 vs. 2011 – A Decline?

In 1.000 Units

| Company | 2012 Units | 2012 Market Share (%) | 2011 Units | 2011 Market Share (%) |
|---|---|---|---|---|
| Samsung | 384,631.2 | ***22.0*** | 315,052.2 | ***17.7*** |
| Nokia | 333,938.0 | ***19.1*** | 422,478.3 | ***23.8*** |
| Apple | 130,133.2 | ***7.5*** | 89,263.2 | ***5.0*** |
| ZTE | 67,344.4 | ***3.9*** | 56,881.8 | ***3.2*** |
| LG Electronics | 58,015.9 | ***3.3*** | 86,370.9 | ***4.9*** |
| Huawei Technologies | 47,288.3 | ***2.7*** | 40,663.4 | ***2.3*** |
| TCL Communication | 37,176.6 | ***2.1*** | 34,037.5 | ***1.9*** |
| Research In Motion | 34,210.3 | ***2.0*** | 51,541.9 | ***2.9*** |
| Motorola | 33,916.3 | ***1.9*** | 40,269.1 | ***2.3*** |
| HTC | 32,121.8 | ***1.8*** | 43,266.9 | ***2.4*** |
| Others | 587399.6 | ***33.6*** | 595886.9 | ***33.6*** |
| **TOTAL** | **1,746,175.6** | **100.0** | **1,775,712.0** | **100.0** |

Cf. TOTAL Units sold in 2013: 1,820,200.0

[Statista2014]

[Gartner2013a]

# Worldwide Smartphone Sales to End Users by Vendor Q3-2016 vs. Q2-2016

In 1.000 Units

| Company | 3Q16 Units | 3Q16 Market Share (%) | 2Q16 Units | 2Q16 Market Share (%) |
|---|---|---|---|---|
| Samsung | 71,733.5 | 19% | 76,743.50 | 22% |
| Apple | 43,000.7 | 12% | 44,395.00 | 13% |
| Huawei | 27,412.7 | 7% | 30,670.70 | 9% |
| Oppo | 24,936.6 | 7% | 18,489.60 | 5% |
| BBK | 19,878.9 | 5% | - | - |
| Others | 181,253.3 | 49% | 17,4061.00 | 51% |
| **Total** | 368,215.7 | 100% | 344,359.8 | 100% |

Based on [Gartner2016], [Gartner2016a] and [ChinaInternetWatch2016]

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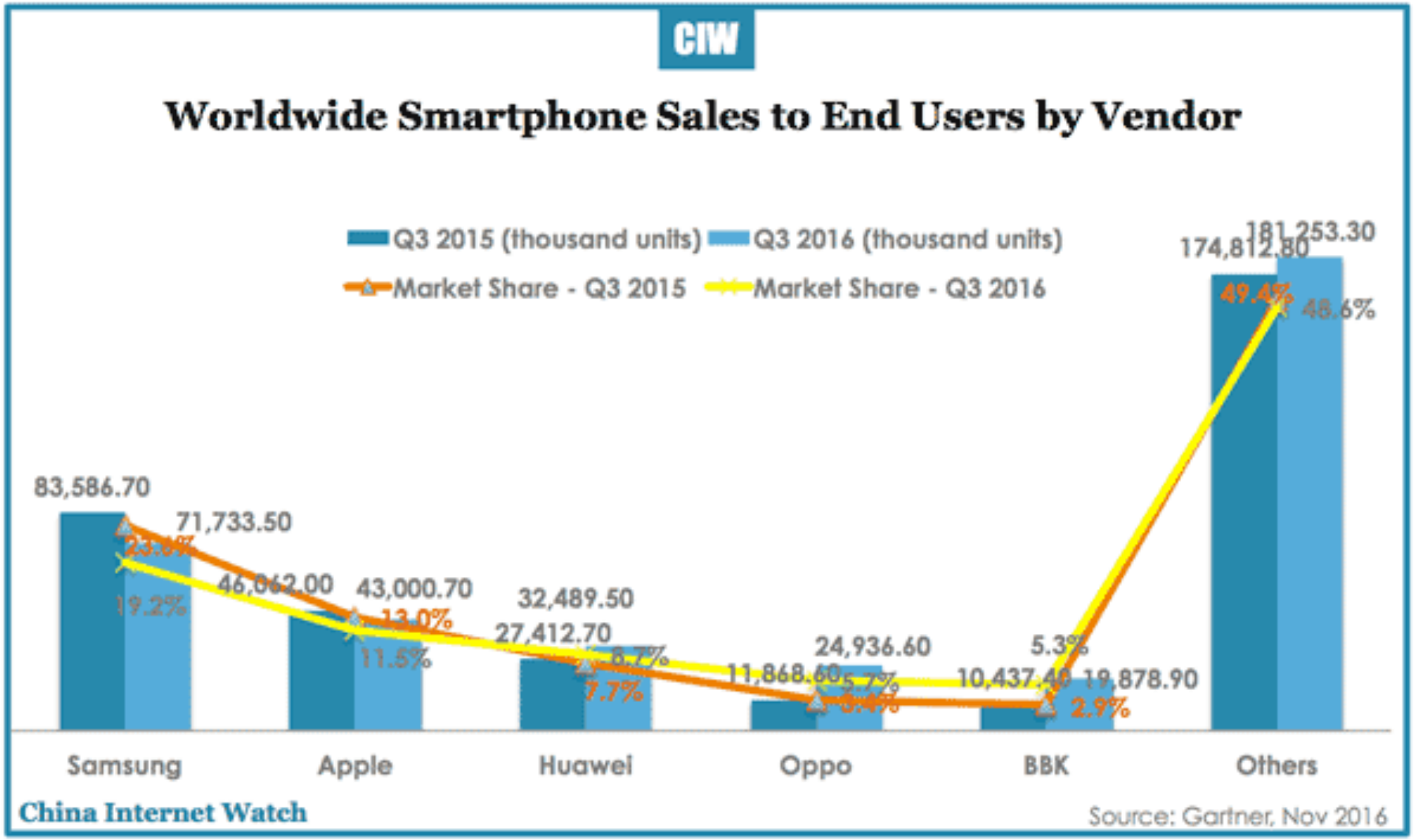
# Worldwide Smartphone Sales to End Users by Vendor Q3-2016 vs. Q3-2015




[ChinaInternetWatch2016]

# Worldwide Smartphone Sales to End Users by Vendor Q2-2016 vs. Q2-2015

In 1.000 Units

| Company | 2Q16 Units | 2Q16 Market Share (%) | 2Q15 Units | 2Q15 Market Share (%) |
|---|---|---|---|---|
| Samsung | 76,743.5 | 22.3 | 72,072.5 | 21.8 |
| Apple | 44,395.0 | 12.9 | 48,085.5 | 14.6 |
| Huawei | 30,670.7 | 8.9 | 26,454.4 | 8.0 |
| Oppo | 18,489.6 | 5.4 | 8,073.8 | 2.4 |
| Xiaomi | 15,530.7 | 4.5 | 15,464.5 | 4.7 |
| Others | 158,530.3 | 46.0 | 160,162.1 | 48.5 |
| **Total** | **344,359,7** | **100.0** | **330,312,9** | **100.0** |

Source: [Gartner2016a]

# Worldwide Smartphone Sales in Q2-2013

- “Smartphones accounted for 51.8 percent of mobile phone sales in the second quarter of 2013, resulting in smartphone sales surpassing feature phone sales for the first time.”

[Gartner2013b]

# Evolution of Mobile Devices


- **Development of device capabilities**
  - Multimedia applications (MP4, radio, video, TV, etc.)
  - Possibility to execute 3rd party software
  - Sensors (microphone, camera, GPS, …)
  - Data Services (Internet connectivity)
  - Short Message Service (SMS)
  - Interactive Voice Response (IVR)
  - General telephony capabilities

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# Evolution of Mobile Devices Examples

© New York Times

1973


2001

© Microoptical


2005

© IBM

2006

2007

2010

2013


2016

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# Mobile Devices Size

- Everybody wants smaller devices.
- Everybody ? …

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# Worldwide Device Shipments by Segment – 2015 View

- Worldwide device shipments and projections by segment show a shift in consumer preferences:

| Device Type | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|
| *Traditional PCs (Desk-Based and Notebook)* | 277 | 251 | 243 | 233 |
| *Ultramobiles (Premium)* | 37 | 49 | 68 | 89 |
| **PC Market** | **314** | **300** | **311** | **322** |
| *Ultramobiles (Tablets and Clamshells)* | 226 | 214 | 228 | 244 |
| **Computing Devices Market** | **540** | **514** | **539** | **566** |
| *Mobile Phones* | 1,879 | 1,94 | 2,007 | 2,062 |
| **Total Devices Market** | **2,419** | **2,454** | **2,546** | **2,628** |

Note: The *Ultramobile (Premium)* category includes devices such as Microsoft's Windows 8 Intel x86 products and Apple's MacBook Air.
The *Ultramobile (Tablets and Clamshells)* category includes devices such as, iPad, iPad mini, Samsung Galaxy Tab S 10.5, Nexus 7 and Acer Iconia Tab 8.

- The reason may be an increasing focus on energy efficiency and weight.

[Gartner2015b]

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# Worldwide Device Shipments by Segment - 2016 View

In 1.000 Units

| Device Type | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|
| *Traditional PCs (Desk-Based and Notebook)* | 244 | 216 | 205 | 199 |
| *Ultramobile (Premium)* | 44 | 49 | 61 | 75 |
| **PC Market** | **288** | **265** | **266** | **274** |
| *Ultramobiles (Basic and Utility)* | 196 | 177 | 173 | 173 |
| **Computing Devices Market** | **484** | **442** | **439** | **447** |
| *Mobile Phones* | 1,917 | 1,887 | 1,910 | 1,933 |
| **TOTAL** | **2,401** | **2,329** | **2,349** | **2,380** |

- Note: The *Ultramobile (Premium)* category includes devices such as Microsoft's Windows 10 Intel x86 products and Apple's MacBook Air.
  The *Ultramobile (Basic and Utility Tablets)* category includes devices such as, iPad, iPad mini, Samsung Galaxy Tab S2, Amazon Fire HD, Lenovo Yoga Tab 3, Acer Iconia One.

[Gartner2016b]

# “Fair” and ecologically friendly Mobile Devices

- Grounded in the idea to develop and market smartphone hardware and software designed and produced with minimal harm to people and planet.

- Strict observation of:
  - Type of raw materials (ecological aspects)
  - Origin of raw materials (political aspects)
  - Lifespan of components and easy repair (durability aspects)

- **Fairphone 1** out of stock
  - **25,000** from the first batch of Fairphones sold in 2013.
  - **35,000** from the second batch of Fairphones on sale in 2014.
- **Fairphone 2** [www.fairphone.com/about/]
  - Over **40,000** phones delivered [Fairphone2016]
  - More available on the online shop and from some retail partners


[Source: news.phonebloks.com]


It is *“not possible to produce a 100% fair phone yet, but by aiming toward this end seeks to raise awareness among consumers and in the mobile industry.”* [Wiki2013]

Based on [Tage2013, Heise15]

- Introduction
- Categorisation of Mobile Devices
- Components of Mobile Devices
  - Accumulators
  - Processors, Memory, and Storage
  - Display
  - Means for I/O

- Categorisation is possible by:
  - Technical characteristics
  - Application aspects
    - Lifespan of an application
    - Functional completeness (Is the functionality comparable to a desktop PC/Laptop?)
    - Size of the device
    - Security features

# Categorisation of Mobile Devices

## Technical Characteristics

- Hardware independence
  - Independent devices
  - Devices with external communication
  - Devices with external security modules
  - Devices with external memory
- Operating system – Characteristics
  - Memory security, file security, access control
  - Security module support, secure I/O, program and system integrity

# Categorisation of Mobile Devices

## Application Aspects 1

- Lifespan of an application
  - Battery consumption, amount of data, and size of memory
  - Data integrity, amount of communication, and costs
- Completeness of the functionality for the end-user
  - Information / Reaction
  - Limitations due to device size
  - Feature Sets

# Categorisation of Mobile Devices

## Application Aspects 2

- Device size
  - Small / integrated devices
  - „Pocket-sized“
  - „Tablet-sized”
  - „Laptop-sized“
- Access to the security module
  - Data integrity, encryption
  - Digital signatures
  - Access control, authentication

# Use Cases

- Different requirements for different kinds of devices:

| | Mobile Phone | Tablet | Laptop |
|---|---|---|---|
| *Number of „Switch-ons“ per day* | low | low | variable |
| *Frequency of use cases* | very high | rather low | low |
| *Duration of usage per task* | variable | short/ medium | high |

Based on [Burckhardt2001]

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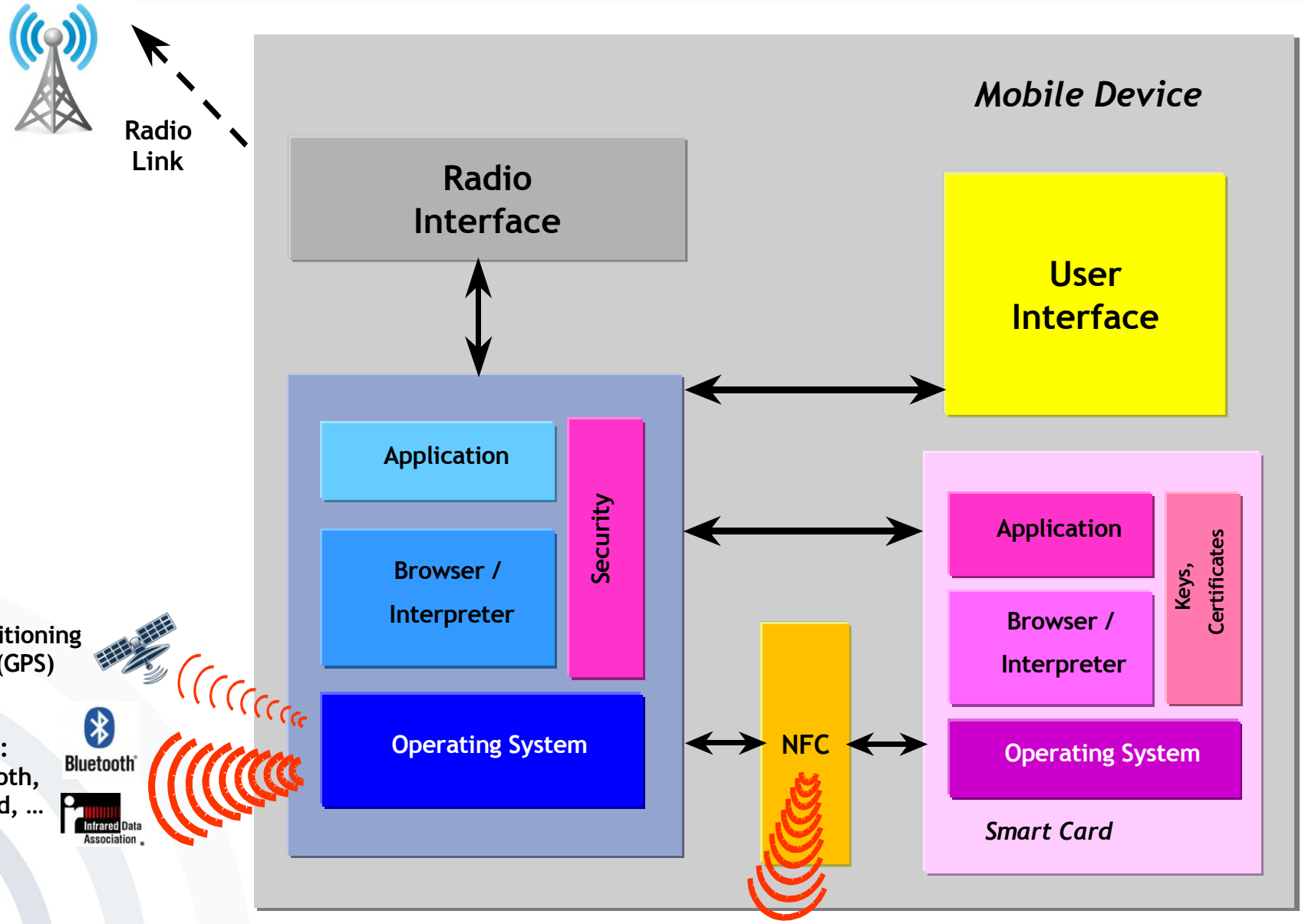
# OS – Functional Architecture




Based on [Posegga2001]

# Size of a Mobile Device

- The size of a mobile device is considerably determined by its:
  - Input Facilities (e.g. keyboard)
  - Output Facilities (e.g. display)

➲ Separation of components (e.g. display in the watch, head-mounted-displays)

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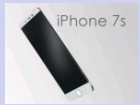
# Accumulators

| Mobile phone | Standby time (in h) | Talk time (in min) | Capacity (in mAh) | Display |
|---|---|---|---|---|
| Nokia 6310 (2001)  | 408 | 360 | Li-Polymer; 1.100 mAh | Graphic 96 x 65 |
| Nokia N-Gage (2004)  | 240 | 120 | Li-Ion; 850 mAh | Color 176 x 208 4.096 colours |
| MDA pro (2005)  | 260 | 480 | Li-Polymer; 1.620 mAh | Touch TFT 640 x 480 65.536 colours |
| T-Mobile Ameo (2007)  | 300 | 240 | Li-Ion; 2200 mAh | Touch TFT 640 x 480 65.536 colours |
| Apple iPhone 4 (2010)  | 300 | 420 (3G) - 840 (2G) | Li-Polymer; 1420 mAh | Touch TFT 960 x 640 16.7m colours |
| Apple iPad Air 2 (2014)  | *Up to 9 hours of surfing the web using 3G data network (10 hours with WiFi)* | | Li-Polymer; 7,340 mAh | Touch TFT 2048 x 1536 16.7m colours |
| Apple iPhone 6S (2015)  | *Talk time: Up to 14 hours on 3G* *Internet use: Up to 10 hours on 3G, up to 10 hours on LTE, up to 11 hours on Wi-Fi* | | Li-Polymer; 1,715 mAh | LED-backlit LCD, capacitive touchscreen, 16m colours |
| Apple iPhone 7 (2017)   | *Talk time: Up to 14 hours on 3G* *Internet use: Up to 12 hours on 3G/LTE, Up to 14 hours on Wi-Fi* | | Li-Ion; 1960 mAh | 4.7-inch (diagonal) LED-backlit widescreen, 1334-by-750 |

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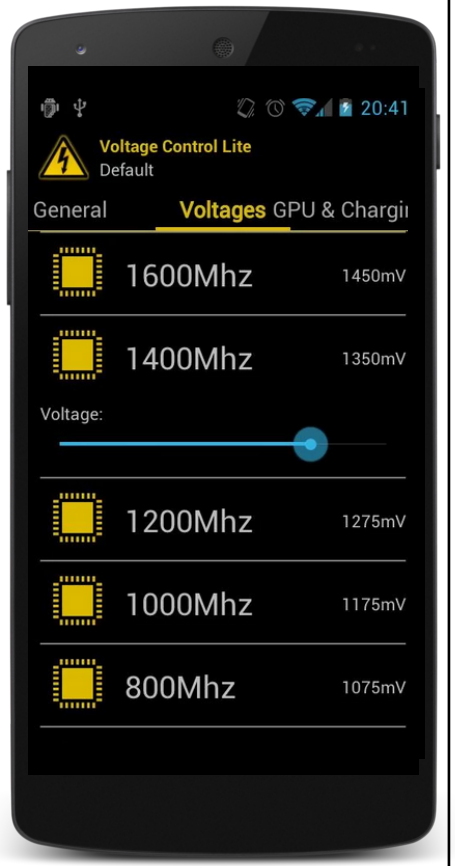
# Processors

- Performance increase
  - Higher clock frequency (but frequency scaling typically comes at the price of higher voltage!)
  - Larger on-die-caches (cache memory) built into the CPU (“on die”) to reduce memory access time
- Power consumption decrease
  - Processor's core voltage (1995: 3.5 V; 2000: 1.35 V; 2013: 1.0 V)
    - Lower bound is the voltage needed to switch a transistor
    - Quadratic relationship between voltage and power consumption

➲ Less heat loss

- Power Management
  - triggered by changes of the energy supply




Picture source: “Voltage Control” Application (Google Play Store) by darek.xan

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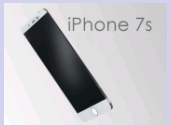
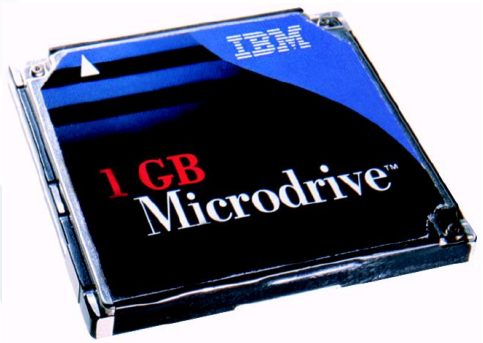
# Processors

## Overview of Mobile Devices

| Logo | Device | Processor | Mhz | MIPS |
|---|---|---|---|---|
|  | Nokia N-Gage (2004) | ARM7 | 104 | ?? |
|  | HTC/T-Mobile MDA (2002) | Intel StrongARM | 206 | 274 |
|  | Apple iPhone 4, iPad (2010) | Apple A4 | 800 (iPad: 1000) | 2.000 |
|  | Notebook (2006) | Intel CoreDuo Processor | 2.000 | < 14.000 |
|  | Notebook (2010) | Intel Core i7 Quad-Core | 3.600 | > 20.000 |
|  | Apple iPad Air 2 (2014) | Apple A8X | 1.500 (Triple-core) | ?? |
|  | Apple iPhone 6S (2015) | Apple A9 | 1,800 (Dual Core) | ?? |
|  | Apple iPhone 7 (2017) | Apple A10 | 2,300 (Octa core) | ?? |

# Memory

- General trade-off between storage on the server vs. storage on the client
- Storage on the client
  - Subscriber Identity Module (SIM)
  - Random Access Memory (RAM)
  - Memory cards
  - Microdrives





- Introduction
- Categorisation of Mobile Devices
- Components of Mobile Devices
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  - Display
    - Liquid-Crystal-Displays (LCD)
    - Organic Light Emitting Diodes (OLED)
  - Means for I/O

# Display

## Liquid-Crystal-Displays (LCD)

- The LCD technology is widespread in the market.
- “Consists of an array of tiny segments (called pixels) that can be manipulated to present information“
- Examples:
  - Dual Scan Twisted Nematic (DSTN)
  - Thin-film Transistor (TFT)


Example: Dynasheet (Toshiba)
1cm, 200g, 2005

# Display

## Liquid-Crystal-Displays (LCD)

- DSTN-Display (Dual Scan Twisted Nematic)
  - Passive matrix
  - LCD displays with passive control have a relatively high latency (generally more than 100 ms). This implies a blurred image with frequently changing picture elements.
- TFT-Displays (Thin Film Transistor)
  - Active (transistor for each pixel)

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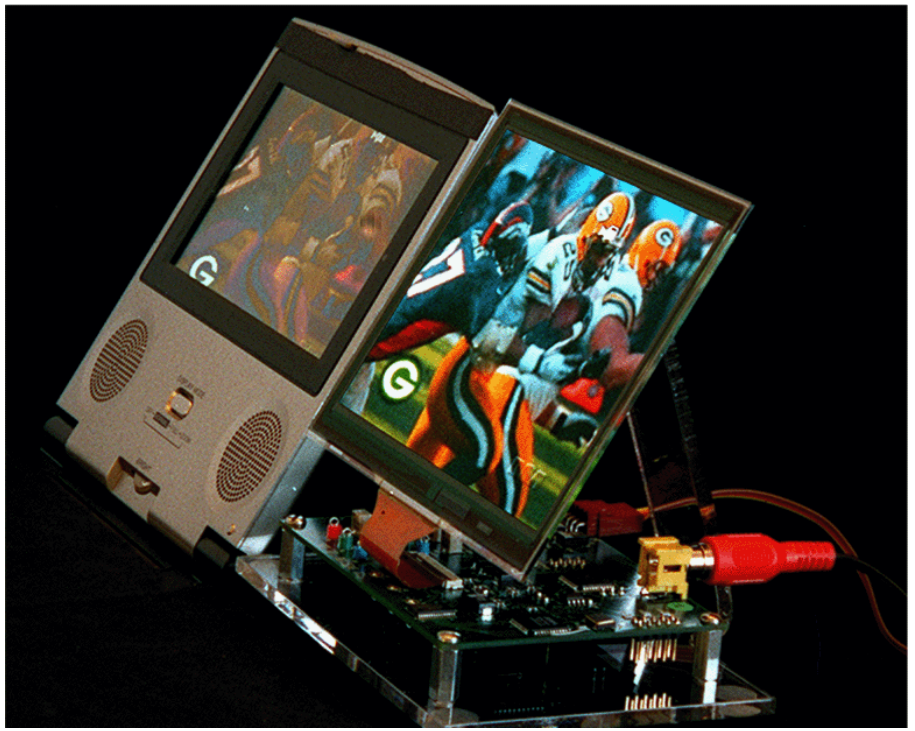
# Display
## Resolution

| Logo | Mobile phone | Display | Resolution | Colors |
|---|---|---|---|---|
|  | Nokia 6310 (2001) | Graphic | 96 x 65 | none |
|  | Siemens S55 (2002) | Color | 101 x 80 | 256 |
|  | Nokia N-Gage (2004) | Color | 176 x 208 | 4.096 |
|  | Samsung E700 (2003) | TFT-Color | 160 x 128 | 65.536 |
|  | MDA III (2004) | Touch TFT | 320 x 240 | 65.536 |
|  | MDA Pro (2005) | Touch TFT | 640 x 480 | 65.536 |
|  | T-Mobile Ameo (2007) | Touch TFT | 640 x 480 | 65.536 |
|  | Apple iPhone 4 (2010) | Touch TFT | 960 x 640 | 16.7m |
|  | Apple iPad 2 (2010) | Touch TFT | 1024 x 768 | 16.7m |
|  | Apple iPad 3 (2012) | Touch TFT | 2048 x 1536 | 16.7m |
|  | Apple iPad Pro (2015) | Touch TFT | 2732 x 2048 | 16.7m |
|  | Apple iPad Pro 2 (2017) | Touch TFT | 2732-by-2048 | 16.7 M colors |

# Display

## Organic Light Emitting Diodes (OLED)

- Polymers can convert electric energy to light.
- Complete layer is thinner than 500 nm (0.5 thousandth part of one mm), luminosity approx. 100W electric bulb.
- 180° viewing angle

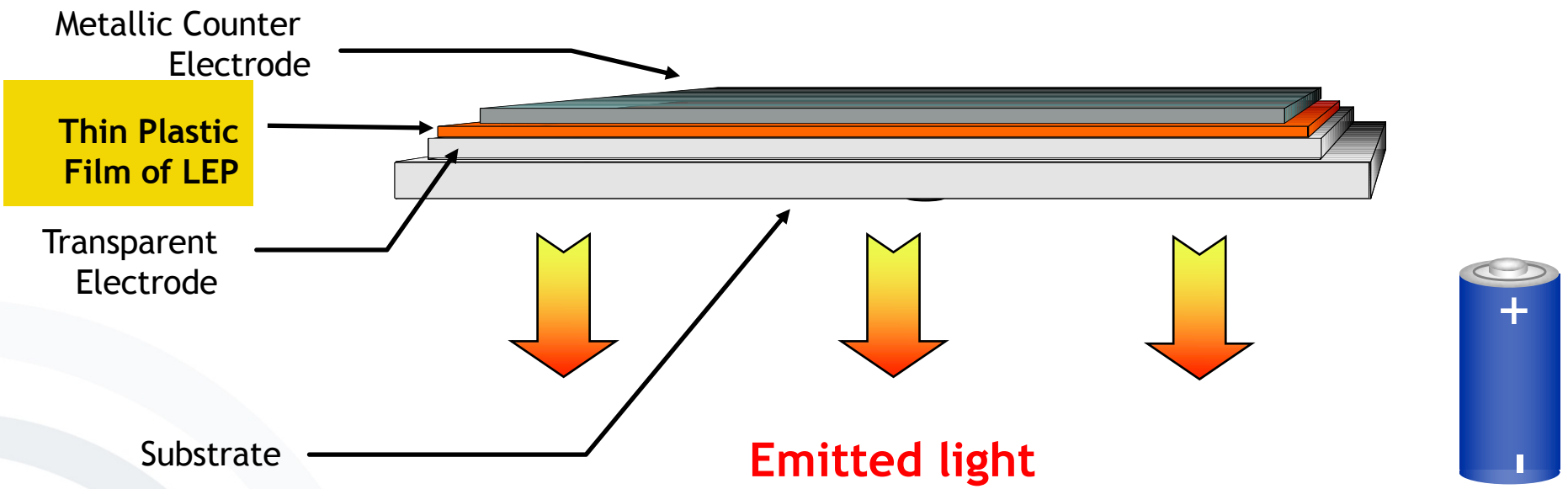


www.opto.com.tw

# Display
## Advantages of OLED

- OLED consist of self lighting polymer molecules:
  - No background lighting is necessary
  - Electric power consumption decreases and longer usage times become possible.
  - Space for extra components
  - Devices can be thinner and lighter.

# Light Emitting Polymer Device




[Covion2006]

# Display

## Organic Light Emitting Diodes (OLED)

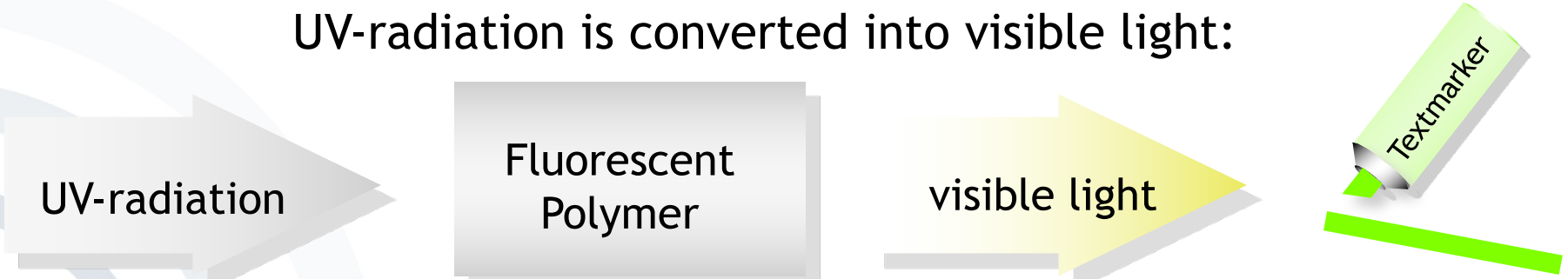
- Polymers are large molecules widely known as plastics.
- *Light Emitting Polymers (LEPs)* are special plastic materials that convert electrical power into visible light.
- A thin film of *Light Emitting Polymer* put between two electrodes will glow ...

# Display

## Organic Light Emitting Diodes (OLED)

***Light Emitting Polymers*** convert electrical power into visible light:

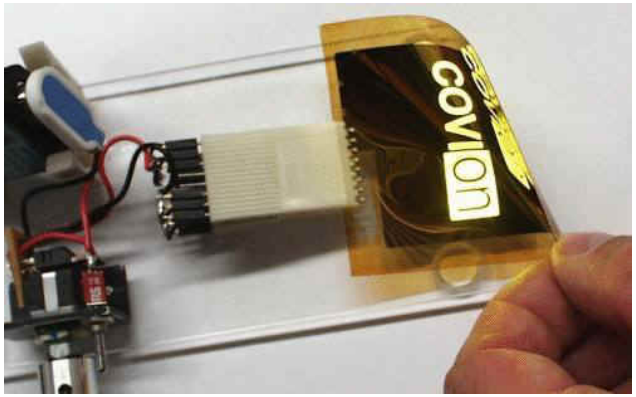

This is related to the fluorescence of polymers where UV-radiation is converted into visible light:




[Covion2006]

# Display
## Organic Light Emitting Diodes (OLED)

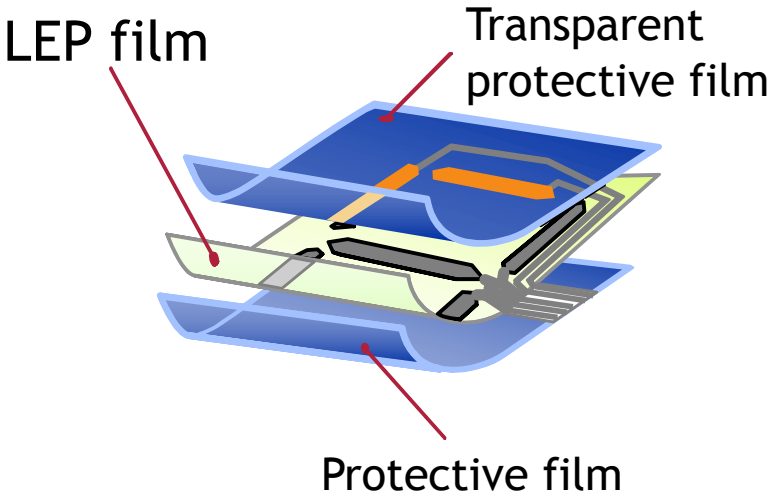
- Because plastic materials are flexible and robust even non-planar displays can be manufactured ...






*Samsung Galaxy Round (2013 in Korea)*

[Samsung2013]




[Covion2006]

# Types of OLED

- Two main types (based on the driving electronics)
  - PMOLED (Passive-Matrix OLED)
    - Simpler electronics, no storage capacitor
    - Lower cost
    - Lower lifetime (due to the higher voltage needed)
    - Limited size and resolution
    - Mostly used for simpler displays, e.g. mp3 players, mobile phone sub-displays, etc.
  - AMOLED (Active-Matrix OLED)
    - Contains storage capacitor to maintain the pixel line state
    - No restrictions on size and resolution
    - More costly
    - Used for higher quality screens, such as mobile phones (Blackberry Priv, HTC One A9, Samsung Z3, Microsoft Lumia 950 XL, etc.)

[OLED-I]

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  - Means for I/O
    - Device Input
    - Personal Area Networks (PAN)

# Input
## "Standardization Battles"

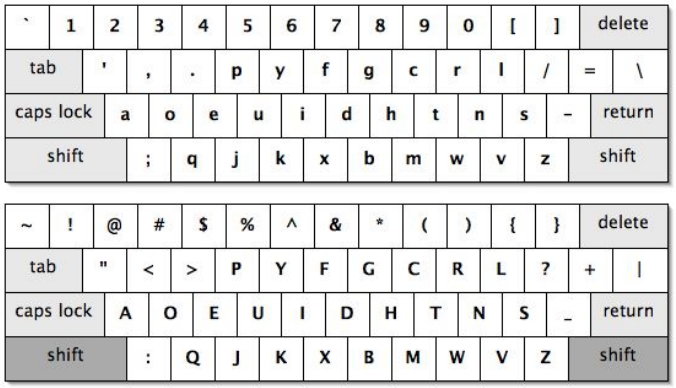
- Excursion "standardization battles": ***QWERTY vs. Dvorak's DSK***
- ***1868*** Christopher Latham Sholes Copyright (goal: minimum key conflicts)
- ***1873*** sale of QWERTY to E. Remington & Sons
- "Jamming" was a problem until 1979. As a consequence, the ball-shaped head technique was invented.

# Input
## "Standardization Battles"

- De-facto standard, high competition
- 1936 Dvorak's Simplified Keyboard (DSK)
- Goals:
  - Keys which are used most frequently are close to each other
  - Change of hands well balanced
  - Frequent keys preferably with strong fingers

- Fact = We all use QWERTY.

➲ ***What did go wrong?***



# Input
## "Standardization Battles"

- QWERTY is an example for market failure in the presence of network effects.
- *"Worse standard dominates a better standard".*
  ➲ *What is the better standard?*
- ***Further problems:*** Lock-in, switching costs

➲ Unfortunately, the case is not as easy!

# Input

## "Standardization Battles"

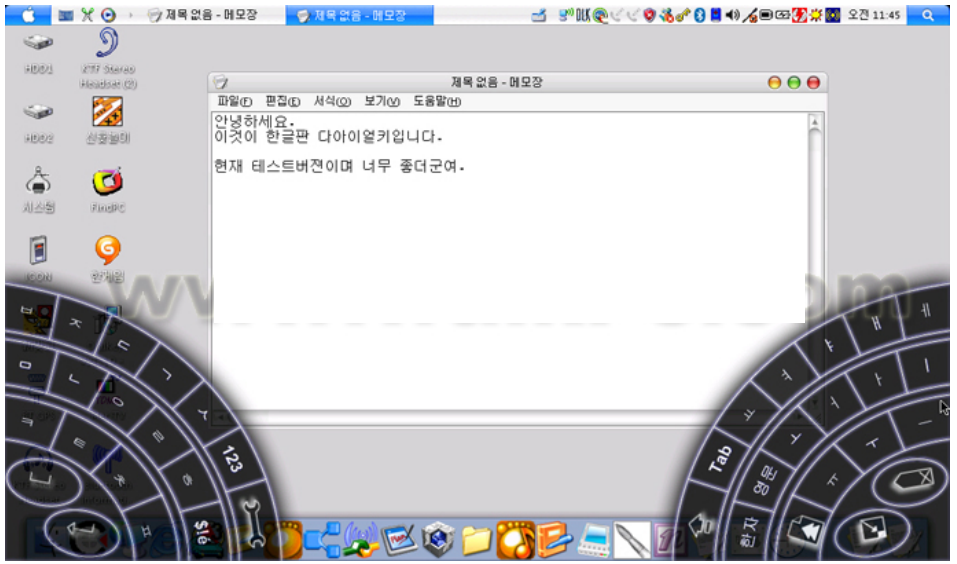
- Often cited US Navy Research Report of 1944 ➲ DSK is more efficient than QWERTY.
  - No official report but a falsely cited internal paper from an officer = Lieutenant Commander August Dvorak!
  - ***Critics:*** Methodological biases: Two test persons of different age and abilities
  - Chaos between 108 and 180 hits per minute - Many contrasting findings
  - *… the QWERTY keyboard appears to be fast enough for almost all users. If you are just driving about in town you do not need a 500 horse-power V8.*" (Poole 1997)
- Things are not as easy as they seem to be!
- For more details see: [LiebowMargol1996].

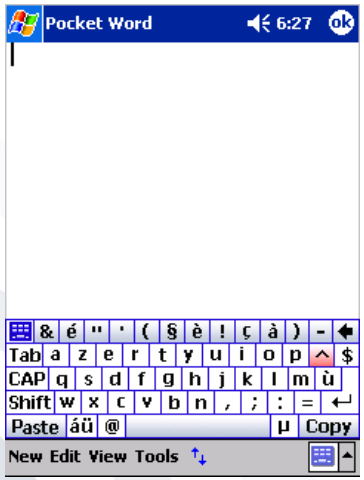
Currently, the following input solutions for mobile devices exist:

- QWERTY-Keyboard
- Palm-Graffiti
- Tegic T9
- Octave
- SWYPE
- Recognition of handwriting
- Speech recognition

mobile business

# Input
## QWERTY-Keyboards

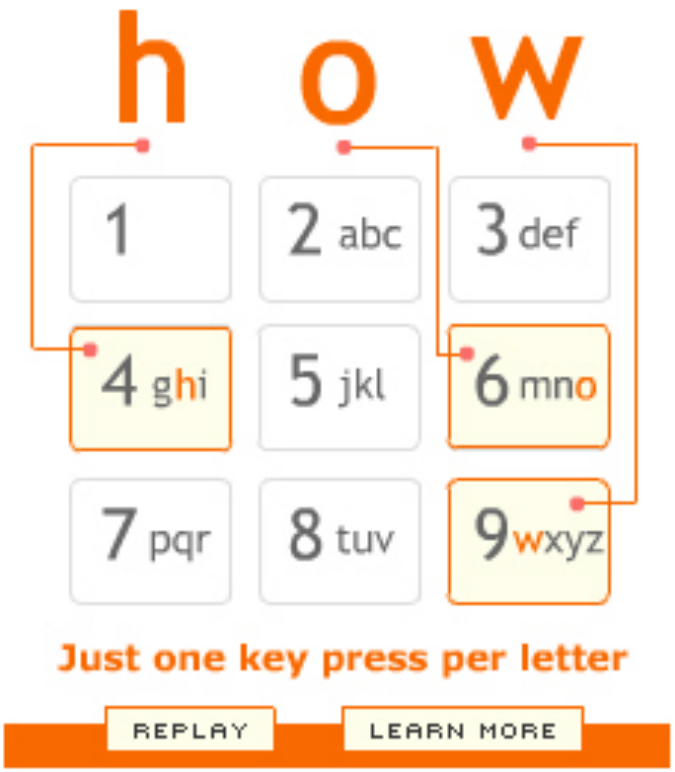

# Input
## PALM Graffiti

- Handwriting recognition software
- Artificial script, based on upper-case characters
- Can be drawn blindly with a stylus on a touch-sensitive panel

# Input

## Tegic Communications T9

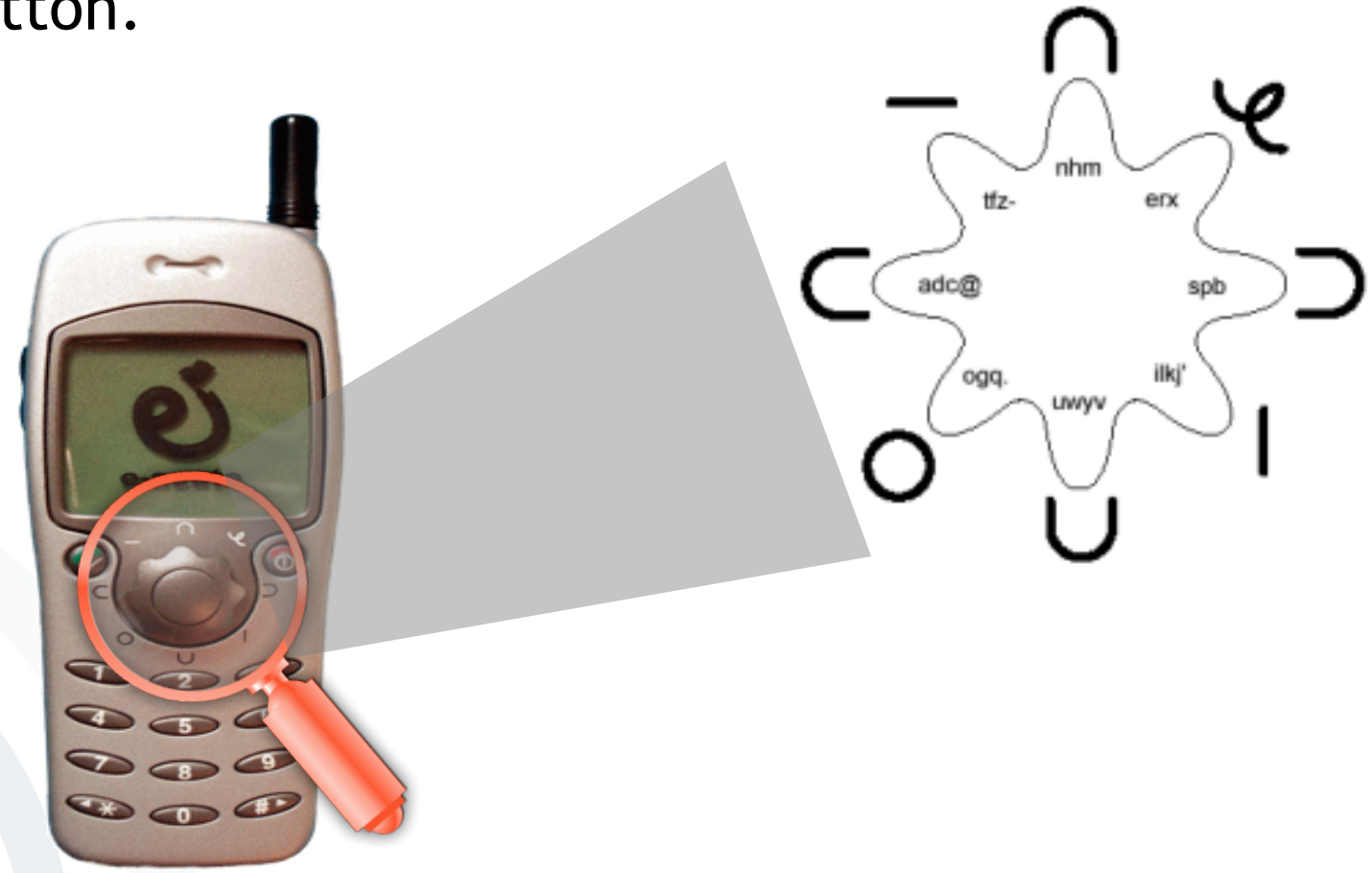
- T9 (*Text on **9** keys)* is a predictive text technology developed by Tegic Communications.
- Widely used by: LG, Samsung, Nokia, Siemens, Sony Ericsson, Sanyo
- Uses a dictionary of words, which is used to look up all the possible words, corresponding to the sequence of keypresses.
- Available in 27 languages



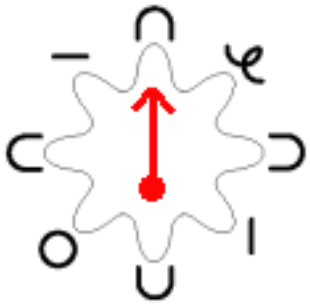

[T92006]

# Input
## Octave

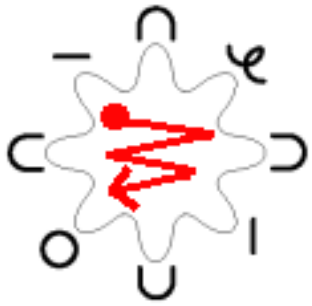
- Characters can be input by either pen or button.



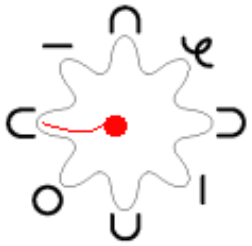
# Input
## Octave



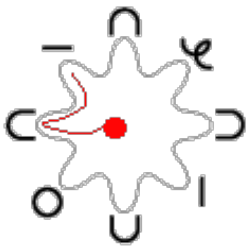
“capital letters”



“reset”



a·



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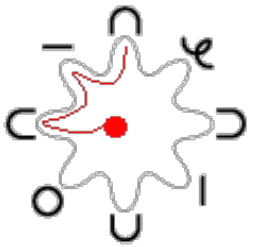

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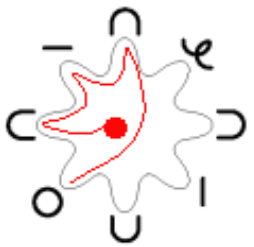


atmo·sphere

# Input
## SWYPE

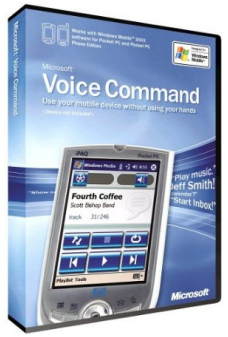

[http://swypeinc.com/product.html]

- Input by sliding a finger or stylus from letter to letter, lifting only between words
- Word is guessed using error-correcting algorithms and language model
- Developed by Swype Inc.
- First commercially available on Samsung Omnia II (on Windows Mobile 6.5), also available for Android

# Input
## Speech Recognition

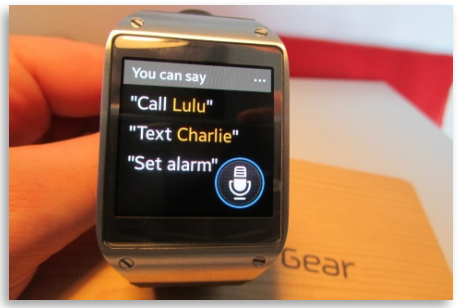
- Translation of spoken words into text
- Supports various applications, e.g. for
  - initiation of phone calls
  - message composition
  - …
- Originally performed directly on PDAs/smartphones
- Nowadays usually provided as a cloud service
  - Voice is recorded and compressed
  - Sound file is sent to a server where the actual recognition process is performed
  - Text is sent back to smartphone
- Examples
  - Apple Siri
  - Google Now
  - Samsung S-Voice
  - Windows Phone Voice Control
  - Blackberry 10 Voice control
  - …
- May become important feature for smart watches
- In contrast, term *voice recognition* refers to *identity* of the speaker, not *what* is said.


[Source: Wikipedia]










[Source: Samsung]

- Introduction
- Categorisation of Mobile Devices
- Components of Mobile Devices
  - Accumulators
  - Processors, Memory, and Storage
  - Display
  - Means for I/O
    - Device Input
    - Personal Area Networks (PAN)

mobile business

# Personal Area Network (PAN)

- Personal environment, short range
- ***Purpose***: Connection of devices in short range, for example mobile device and printer.
- Replaces cable-connections:
  - **I**nfrared **D**ata **A**ssociation (IrDA)
  - Bluetooth
  - Near Field Communication (NFC)

# Personal Area Network (PAN)

## Infrared

- IrDA: Infrared Data Association (1993):
- Standardized infrared-protocols
- Asynchronous, serial connections up to 115 kbit/s (Serial Infrared) or 4 Mbit/s (Fast Infrared)
- Point-to-Point
- Protocol-family for various purposes

- Exemplary applications:
  - Transmission of mobile business cards
  - Sales data extraction from cigarette vending machines
  - Connection between mobile and laptop
  - Wireless printing
  - Remote control for consumer electronics, e.g. TVs

# Personal Area Network (PAN)
## Infrared

- Attributes:
  - Wireless
  - Range of up to 10 meters
  - Illumination-angle 15° - 30°
- Disadvantages:
  - **Sounding:** If the infrared-ray misses the target
  - Optical connection required
  - Short interruptions of the optical connection, e.g. between laptop and mobile phone in trains, lead to complete network-interruption.

# Personal Area Network (PAN)

## Bluetooth

- Frequency range of 2.4 GHz
- Simple and cheap possibility to set up ad-hoc networks of limited range (up to 10 meters)
- No official standard, but de-facto-standard
- Consortium: Ericsson, Intel, IBM, Nokia, Toshiba, etc.
- v4.2 (2014) improved speed, privacy, and connectivity (support for the Internet of Things)
- Broadly supported by related industries:
  - Computer hardware
  - Software
  - Consumer electronics
  - …

Bluetooth™

# Personal Area Network (PAN)

## Popular Bluetooth Applications

Sound transmission
(to earphones, headphones
or Hi-Fi equipment)

Wireless communications between devices
(Bluetooth-Headset)

# Personal Area Network (PAN)

## Bluetooth Applications

- Connection of periphery-devices (headsets, keyboards, mice, etc.)
- Setting up of ad-hoc networks for spontaneous data exchange
- Ad-hoc connection of different networks (e.g. laptop ⇔ mobile or phone ⇔ GSM ⇔ net)
- Applications similar to applications based on infrared technology
- Weaknesses of infrared technology were overcome
  - Increased bandwidth (up to 865.2KBit/s)
  - No optical connection between devices necessary
  - Expanded range (up to 10m)
  - Allows setting up of ad-hoc networks instead of point-to-point connections

# Personal Area Network (PAN)

## Near Field Communication (NFC)

- Enables radio communication between
  - two NFC compatible devices (two active devices),
  - An (active) NFC device and an (unpowered, passive) tag
- NFC based on existing radio-frequency identification (RFID) standards
- Range: 10 cm or less
- Transfer rates between 106 kbit/s and 424 kbit/s
- Three major modes of NFC
  - Reader/Writer Mode
  - Card Emulation Mode (referred to as "Digital Wallet")
  - Peer-to-Peer Mode


[NFC]

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