ENVIRONMENTAL IMPACT OF NEW GENERATION WIRELESS SYSTEMS

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Introduction

- **The mobile phone is an established part of everyday life, not only in developed countries but also across a wide area of the developing world**
- **Number of mobile phone subscribers world-wide will exceed 900 million by 2003, with the majority in the Asia-Pacific Region**
  - **China Telecom is now the largest operator**

Introduction

- **This has introduced a new, amorphous, wireless environment**
- **Overlays, and may replace, traditional environment of broadcasting transmitters (mainly)**
- **Present dominant mobile paradigm is the integrated handset transceiver, carried in a pocket, but held against the head when transmitting**

Introduction

- **This mode is unlikely to remain dominant in the long term**
  - **This will change the user's environment**
  - **User's exposure time will also increase with new forms of use**
- **Signals from, and patterns of, base stations also changing**

Samsung cellphone watch

New Nokia 3650
Symbian OS
12-bit digital camera
GPRS & HSCSD
Bluetooth 1.1
WAP 2.0
XHTML – supports i-Mode
J2ME
MMS
RealOne Mobile Player

Recent and Emerging Usage Scenarios

- SMS Messaging
- WAP and i-Mode
- Hands-free kits
- Bluetooth hands-free
- MMS (Photo messaging)
- html on PDA (etc)
- Bluetooth link to PDA
- MP3
- Satellite-mobile
- IEEE 802.11 WLAN
- GPRS/HSCSD/EDGE
- 3rd Generation
- Improving graphics
- Streaming media
- Wearable computers & PAN/BAN
- 4th Generation
- MIMO
- Ad hoc networks
- Ultra-wideband (UWB)

SMS Messaging

- **Phone normally held in the hand when transmitting, hence distant from head**
  - **A ‘vsiual’ mode of operation**
- **Perception is thus that any hazards are reduced, (presumes that effects in the hand are less significant than any in the head)**
- **Phone emits control signals while close to body (in a pocket, etc.), as for any usage**

SMS Messaging

- **Uses relatively low average power, transmitted in the Slow Associated Control Channel (SACCH) time slots of the GSM multiframe**
- **At least one device was designed specifically for SMS: Motorola V100, having a small full keyboard, a large screen and no built-in audio - unsuccessful (needed 3 hands)**
- **Some handwriting-recognition phones, but most usage is one-handed ‘txting’**

WAP and i-Mode

- Used in essentially the same way as SMS; the signal is like GSM voice
- GPRS will change this – uses more time slots, but traffic ‘bursty’
  - This will change the time-wise pattern of SAR
  - Not significant, as we consider the ‘worst case’?
- But both hands may be close to the antenna when transmitting (more 2-handed use?)

Hands-free kits

- On the body: fundamental change – main transmitter now usually adjacent to abdomen
- Concerns for pregnant users?
- Concerns about other effects in lower abdomen? More significant than the hand? Less significant than the brain?
- We have to acknowledge a degree of public concern, even when there is little science
- Effect of cable? Testing now necessary, even if fields minimal
- In the car: low interaction if away from body

Bluetooth hands-free

Ericsson Bluetooth wireless headset

Bluetooth hands-free

- **Transmitter becoming a ‘dumb box’ – even more likely to stay adjacent to abdomen**
- **Bluetooth power very low (1mW at 2.4 GHz) unless in high-power mode for WLAN (100mW)**
- **Still a source of public concern, because it radiates?**
- **Public will expect safety-compliance evaluations to be performed**

MMS (Photo messaging)

- **Interaction much like SMS**
  - **‘Small screen’ visual mode, away from head**
- **It is hoped that this will drive demand for more graphical services**
  - **It may also drive a demand for easier access to rich content than through URLs**
- **This will improve demand for bandwidth and hence 3G business case**

html on PDA (etc)

- For ‘serious’ work with PDA or laptop
- Link via cable, irDA or Bluetooth, or:
- May use integral PDA-phone (Trium Mondo, Handspring Treo etc – uptake not great?)
- For cable or Bluetooth, transmitter could be adjacent to abdomen for long periods; Bluetooth introduces extra signal

MP3

- Strong marketing push for downloading and playing of MP3 files on phone-like device
- Actual uptake not known – small?
- Used with stereo earpieces
  - Much like hands-free kit
- Download phase much like WAP usage
  - Could be high usage?

Satellite-mobile

- Uptake not large
- Handsets like large ‘mobile phones’
- Antenna must point ~upwards
- Use in pocket (etc) not an option
- Higher power than GSM (from 0.45W for Iridium to 0.625W for ICO)
- Any future scenario will still need antenna near head (unlike terrestrial)

IEEE 802.11 WLAN

- **802.11b: 2.4GHz, 11Mbps (max.), DSSS, 100mW max. (in EU – 1W in USA), Gain 6dBi max., Duty cycle up to 100%(?)**
  - **Range: 50 – 130m (max. – min. data rate)**
- **802.11a: 5GHz, 54Mbps (max.), OFDM, Power similar to 802.11b (spectrum problem in Europe)**
  - **Range: 20 – 50m (max. – min. data rate)**
- **802.11g: 2.4GHz, 22Mbps (max.), OFDM, (proposed)**

IEEE 802.11 WLAN

- **MAC layer: CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance)**
  - **handshaking additions to CSMA/CD for wired LANs, to reduce hidden node problem**
  - **C.f. TDMA/CDMA for mobile phone paradigms**
- **Very wide bandwidth per channel**
- **Low access charges and low-cost user-controlled base stations**

IEEE 802.11 WLAN

- **Mainly used with laptops or PDAs at present**
- **No general handover mechanism**
- **Free/cheap access in ‘Starbucks’ coffee shops**
- **Very popular in the USA: deployed by enthusiasts as *ad hoc* free-access nodes**
  - **Could become ad hoc network?**
- **Probable standard facility in future high-performance mobile units – where will the transmitter be transmitter on the body?**
- **Could be rivals to 3G/4G?**

IEEE 802.11 WLAN

- **Base stations could be an environmental issue**
  - **Power is low, but numbers could become pervasive**
  - **There could be public ‘worries’**
  - **Interference problems possible, especially as 2.4GHz band gets more crowded**

GPRS/HSCSD

- **Enhanced data modes in GSM – use more of the GSM burst pulse positions**
  - **implies higher average power (also at base stations)**
  - **SAR multiplied by no. of pulses per frame?**
- **GSM: 9.6 kbps; HSCSD: up to 43.2 kbps; GPRS: 172.2 kbps theoretical, 28.8 kbps probable limit**
- **Difference is mainly a cost issue: HSCSD ties up a virtual circuit (costly); GPRS is always on, charged per packet**
- **Facilitate greater use of WAP/iMode/html**
- **Will be popular if ‘visual’ modes succeed**

EDGE

- Enhanced digital GSM evolution – uses multi-level modulation
- up to 384 kbps
- Average power similar to GPRS?
  - Environmental issues much the same?
- Facilitates video (but no handover?)
- Could challenge 3G, as cheaper to deploy

3rd Generation

- **Third generation = UMTS or IMT-2000**
- **Several frequencies from 1880 MHz to 2200 MHz have been allocated (others later)**
- **W-CDMA (=FDD Europe)/TD-CDMA (USA)**
- **128 kbps to 2 Mbps, depending on distance**
- **Peak output power lower than for GSM, but the duty cycle will be very different (100%)**
- **Some coexistence with EDGE is likely**

3rd Generation

- **UMTS Forum identified applications: ‘Customised Infotainment, Mobile Intranet/Extranet Access, and Multimedia Messaging Service’**
- **All of these require a large high-resolution screen. Current designs similar to video-enabled 2.5G phones, but ‘wearable’ headset paradigm would give better interaction**
  - **C.f. Xybernaut/Hitachi ‘Poma’**

3rd Generation

- **In UK, there is now a rush to establish new base station sites**
  - **Especially churches, where antennas can be hidden in the spire!**
- **Increased density of base stations (with lower power than earlier phases) needed to allow use of high data-rate (e.g. video)**
- **Small macrocell/microcell antennas also being deployed in streets etc.**

Improving graphics

- **Graphics gives far higher information rate into human than audio or text: it will soon become the normal expectation in personal communications, hence generating demand for more bandwidth and higher usage**
- **JPEG/MPEG compression a major factor in reducing data**
  - **Current – awful! (~2500 1-bit pixels)**
  - **Emerging MMS: ~10^4 12-bit pixels**
  - **PDA: ~10^5 16-bit pixels**
  - **Computer screen: ~10^6 24-bit pixels**

Improving graphics

- **Streaming media: ~10^6 24-bit pixels @50Hz refresh rate (MPEG compressed)**
- **'100 Megapixel display' - 4π steradian VR using orientation-sensing headset**
- **All these things are possible now and are only delayed by lack of bandwidth, but it <u>can</u> be delivered now by 802.11, and soon by 3G (with limitations) and later by 4G (2010)**
- **Hence usage paradigm and market will soon be established**

Wearable computers & PAN/BAN

- **Rich graphics plus audio, mouse and keyboard input already available with wearable computers**
  - **add 802.11 and we have a development platform for future personal communications**
- **Get rid of wires to make more acceptable**
  - **use Bluetooth to create body-area network (BAN)**
  - **Can also link to nearby objects, hence ‘personal area network’ (PAN)**

Wearable computers & PAN/BAN

- Hence body likely to live in a ‘haze’ of Bluetooth signals, plus one multiband high-power transmitter
- Strong possibility that in the future the main transceiver could be separated from the human-computer interface (HCI) since separate units can be linked by Bluetooth
- Hence transmitter could be placed at any convenient location on the person
  - Reduces safety concerns (not for satellite!)

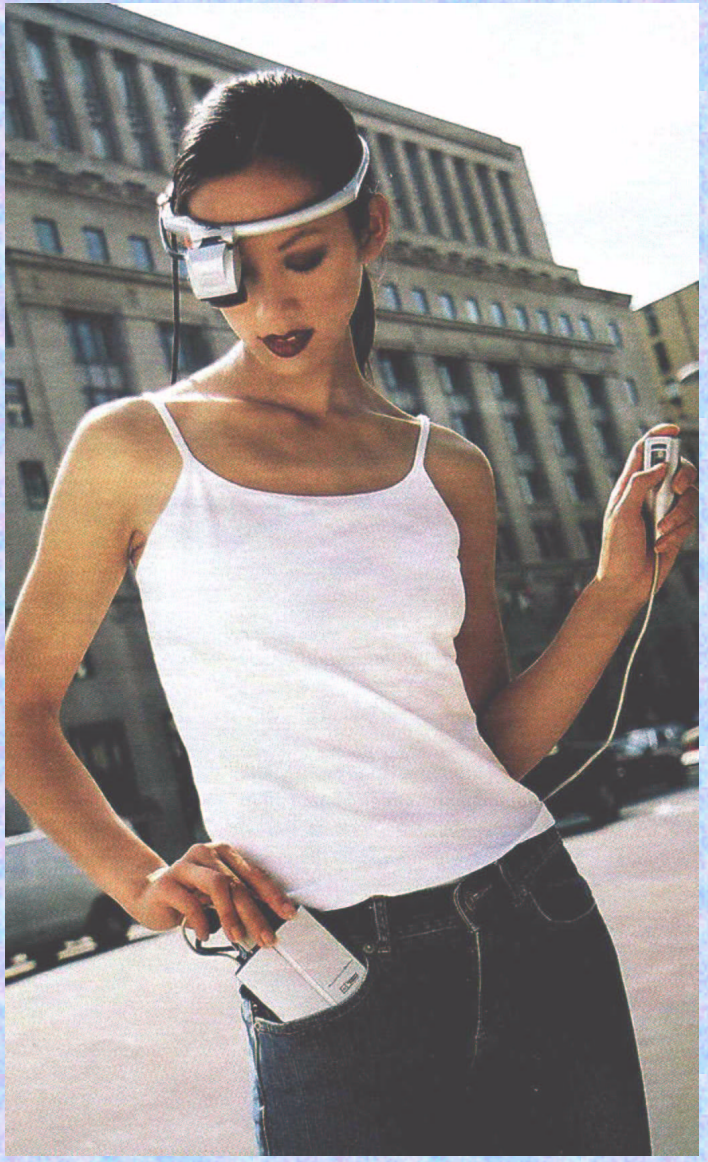
Wearable computers & PAN/BAN

Steve Mann, Toronto Univ

MIT Media Lab

Xybernaut mobile assistant

Wearable computers & PAN/BAN



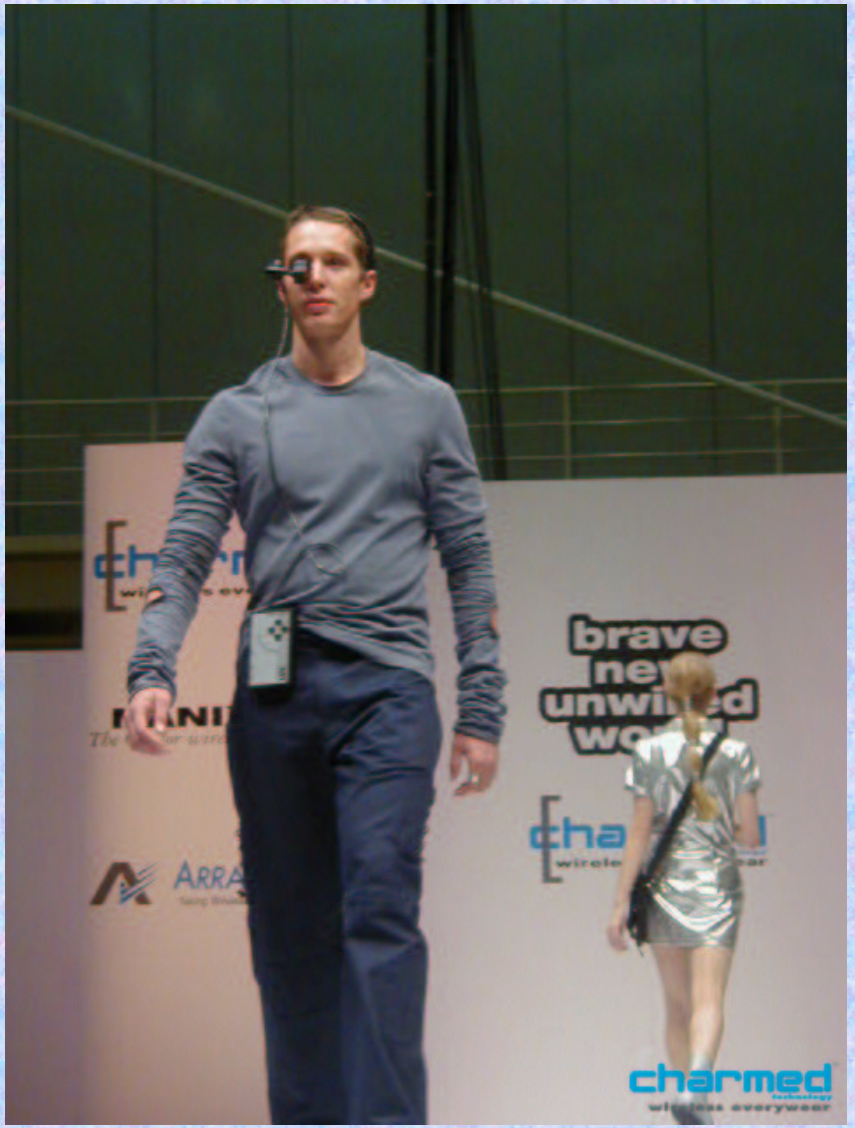
Xybernaut POMA

Also sold as Hitachi WIA –Wearable Internet Appliance

(separate audio and WLAN ability)

Screen and ‘mouse’ are as good as PC

Wearable computers & PAN/BAN



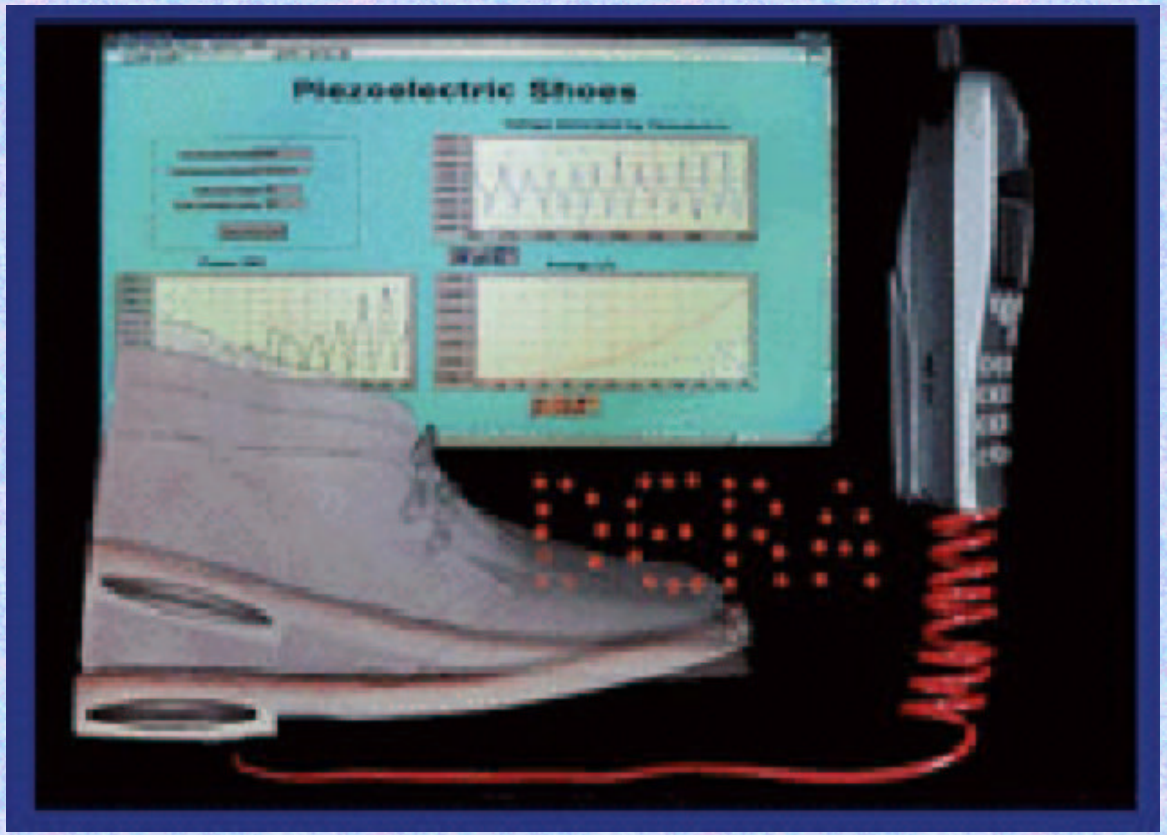
Tekgear models at 'Charmed' wearable computer fashion show

Wearable computers & PAN/BAN

Power supply in shoe (Freeplay/QinetiQ)

Development stopped, but could re-start?

Transmitter could be in shoe as well



4th Generation

- Coming very fast! – could overtake 3G
- All-Internet Protocol
- ~40Mbps, using more frequency bands than 3G
- Gives more bandwidth than needed for video
  - How will it be used?
  - Real-time VR, or just bursts for downloads?
- Surely the handheld phone paradigm will be obsolete by then?

MIMO and ‘Smart Antennas’

- **Recent, rather amazing, realisation that multipath gives increased bandwidth**
  - **6 polarisations(!) or independent beams**
  - **City dwellers have the advantage**
- **Subject of much work at present**
  - **Will it be practical?**
- **Very complex intelligent antennas needed**
- **Simpler ‘smart antenna’ options (tracking beams, SDMA) more likely**
  - **Would reduce public EM environment**

Ad hoc Networks

- **Bluetooth ‘piconet’ already becoming an established principle**
- **Similar principle being developed for vehicles on highway (handing messages on until they reach a base station)**
- **Wider applications known to be under consideration**
  - **Reduces need for base stations**

Ultra-wideband (UWB)

- **Recently-emerging WLAN technology**
- **Uses spread spectrum methods over a band as wide as 3.1 to 10.6 GHz**
- **Transmitted signal: very narrow pulses (<0.5ns)**
- **Uses pulse position modulation (PPM)**
- **Transmitters radiate only a very low power, so that the signal appears as ‘harmless noise’ in the environment (local EMC problems?)**

Ultra-wideband (UWB)

- **Wideband pulses sound like an environmental problem, but what would receive them?**
  - **Antenna design very difficult, so ‘accidental’ receivers unlikely?**
- **Standard being drafted by IEEE 802.15 sub-committee**
- **Could overtake 802.11, 3G and 4G?**

Other Technologies

- **LMDS – local multipoint distribution systems (high microwave frequencies)**
- **High-altitude platforms (airship etc) for base stations**
- **Power-line telecommunications**
- **TETRA – much like GSM, except for low frame rate**
- **DECT – low power (more interest in India?)**

Summarising the Implications

Summarising Implications

- **Mobile phones already have as much processing power and Internet bandwidth, and almost as much graphical output ability, as the PCs of ~10 years ago**
- **They will rapidly catch up with today's PCs, especially as the market is much larger**
  - **Could take over PC's role?**
- **We need to try to foresee how they will be used (likely to be a multiplicity of ways)**
  - **Leads to wide sociological questions**

Summarising Implications

- **Today's EM environment of low density of high-power (e.g. broadcast) transmitters likely to be replaced by a high-density 'cloud' of lower-power transmitters**
- **Powers are being kept down, so EMC problems will not be severe or insuperable**
  - **Still problems in aircraft – what solutions? More use of coding?**
  - **EMC problems between very close devices**

Summarising Implications

- **Health implications will not be greatly different from today, <u>unless</u> a non-thermal mechanism is found**
  - **Further refinements to dosimetry still needed**

Summarising Implications

- **There appears to be an evolutionary path:**
  - **Broadcasting transmitters →**
  - **1st and 2nd generation base stations →**
  - **3rd and 4th generation base stations (greater number, lower powers) →**
  - **Ad hoc network**
- **Che sarà???**

Summarising Implications

EM Dosimetry issues

- **We have had good success in the past:**
  - **Detailed models of the body (MRI)**
  - **FDTD with PML**
  - **Hybrid FDTD-MoM models**
  - **Use of parallel computers**
  - **Accurate base-station models**
  - **Thermal models**

Summarising Implications

EM Dosimetry issues (computational)

- **Needs for the future:**
  - **Models of the whole body (male, female, children, main racial groups**
  - **Models and understanding at the bio-cellular level**
  - **Use of exact waveform (for non-thermal effect studies)**
  - **Elimination of FDTD ‘staircasing’ (finite elements?)**
  - **Treatment of non-linear and ‘exotic’ media**

Summarising Implications

EM Dosimetry issues (physical)

- **Needs for the future:**
  - **More realistic measurement systems (body models that do <u>not</u> exclude bone)**
  - **Methods of measurement of the real power radiated from the phone**

Summarising Implications

Other EM issues

- **Needs for the future:**
  - **Propagation models to predict environment for very complex systems (e.g. MIMO, UWB, ad hoc networks)**
  - **Smart array antennas (integrated with computer controller)**
  - **UWB antennas**