Pervasive Computing for a Nomadic Lifestyle *

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*** Lessons Learned from Project Oxygen**

How Pervasive Is Computing?

- **>1.5B mobile phones**
  - China, USA, Japan, Germany, Italy, …
- **>300M pagers**
  - USA dominates
- **>120M laptops**
- **>2.3M hotspots by 2007**
  - China, Europe, US, …
- **>16M PDAs**
- **. . .**

⇨ **People and devices are increasingly mobile, so technologies must be developed to support this nomadic lifestyle**

Some System-Level Challenges

- **Pervasive:** Be available everywhere, at any time, for anybody
- **Nomadic:** Allow people and devices to move around freely
- **Embedded:** Live in our world, sensing and affecting it
- **Human-centered:** Understand and respond to human intent; solve real problems
- **Non-intrusive:** Preserve privacy while ensure security
- **Adaptable:** Provide flexibility in response to changes
- **Eternal:** Must never shut down or reboot
- **Organic:** Allow applications and services to be added easily
- . . .

Some Technical Challenges

- Devices
- Networks
- Security and Privacy
- Interfaces
- Operating Systems
- Collaboration
- Information Management
- . . .

Smart Devices

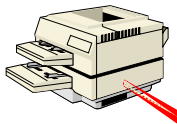
- **Many special purpose devices ⇨ One flexible, anonymous device**

- **Technical challenges**
  - A new, programmable, energy efficiency computer architecture
  - Software-centric application development
  - Customizable, yet provide security and preserve privacy

Networks for a Nomadic Lifestyle

- **People and devices will be moving, and available computing resources will be changing**
- **New technologies must be developed to support this context-aware, nomadic lifestyle**
  - Location awareness: *Where am I?*
  - Resource discovery: *What is available near me? How do I find them?*
  - Session migration: *What's the best way to achieve connectivity?*
  - P2P computing and communication
  - Ad hoc networks
  - Sensor networks
  - Privacy and security
  - . . .

Nomadic Networks



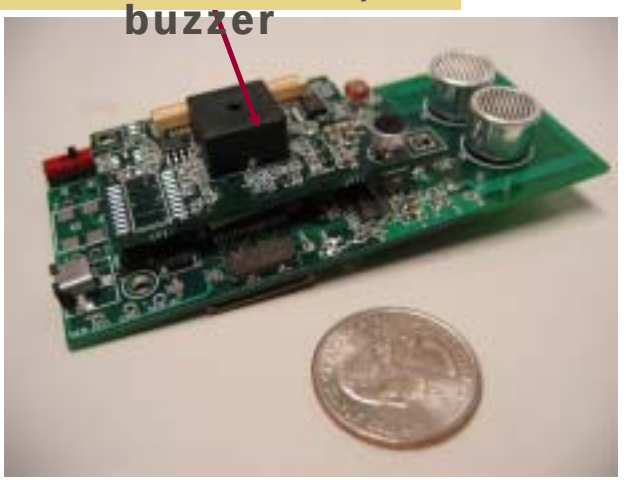
Print this on the nearest color printer.

Resource Discovery

Indoor Navigation

Stream Migration

Temperature, light, sound sensors, buzzer



Location Aware Sensing

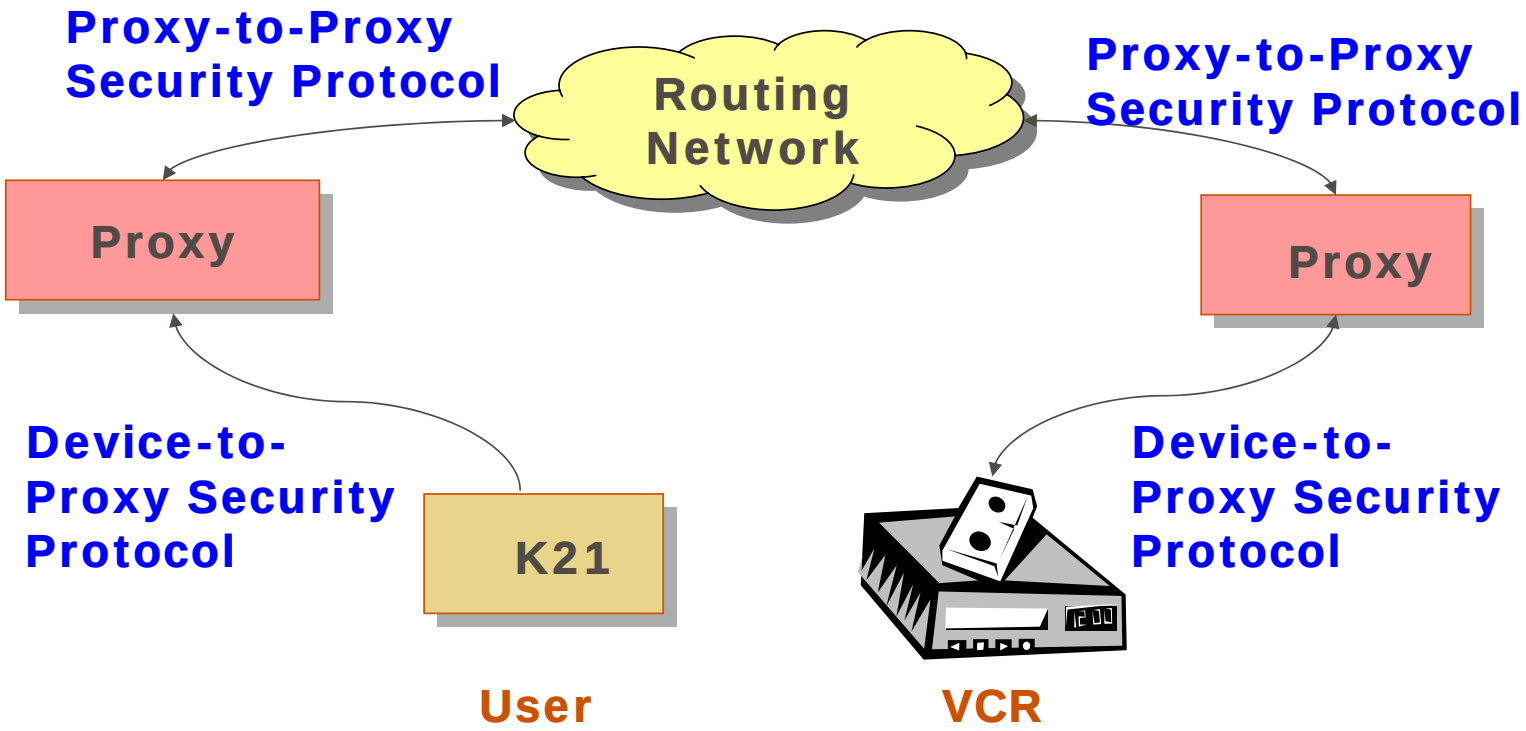
Cricket Location Supp

video

Security and Privacy

- **How can we improve security of cell phones, PDAs, and other mobile devices?**
  - OS improvement to malicious attacks
- **How can we *securely* utilize a multitude of inexpensive, potentially untrustworthy, potentially indistinguishable devices?**
  - Security automation of cheap devices (proxy-based protocols?)
  - User/proxy authentication for untrusted devices
- **How can we ensure that privacy is preserved**

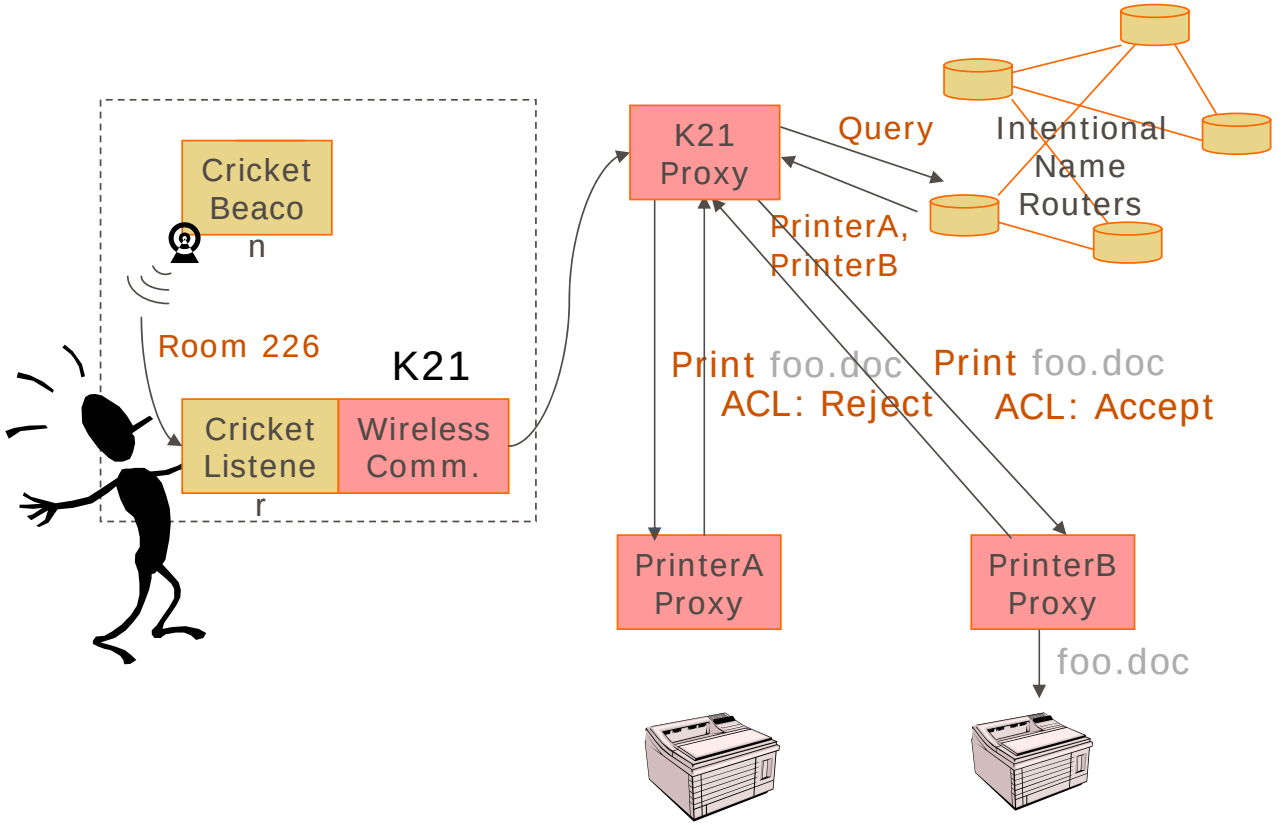
Proxy-based Security Protocols



K21= Electronic ID + Location + Wireless

Putting It All Together . . .

"Print foo.doc on nearest printer"



Proxy-based Security & Location-based Service

We Need Anthropomorphic Interfaces

- **Computers should interact with humans in the same ways humans interact with humans**
- **Next-generation interfaces should be human centric:**
  - Carry on a conversation with the user
  - Combine speech, vision, gesture and sketching
  - Permit multi-modal interactions
- **Technical challenges**
  - Monolingual ⇨ Multilingual systems
  - On-line interactions ⇨ Off-line delegation
  - Uni-modal ⇨ Multi-modal interactions
  - Adaptation and learning

Multilinguality video

Delegation video

Multimodality video

Adaptation video

Operating Systems

- **Pervasive computing systems need to support dynamic assembly of distributed applications**
- **The operating system must be able to**
  - Continuously adapt to changes in user locations and needs
  - Respond to component failures and newly available resources
  - Maintain continuity of service as the resources evolve

Summary

- **Pervasive computing is fast becoming a reality**
- **Many fundamental technological problems must be solved**
  - Devices
  - Networks
  - Security/Privacy
  - Interfaces
  - Information management
  - . . .
- **Major challenges include robustness, re-configurability, privacy, and security**
- **An overarching architecture and SW infrastructure is critical**

To Be Successful, Taiwan Should . . .

- **Adopt a software-centric approach**
  - The value-added in the end result is largely in software
- **Promote a systems perspective**
  - High level conceptualization, not low level mechanism
- **Acquire an application-driven perspective**
  - Intel doesn't care much about what people do with the PCs
  - Microsoft cares about what people do with PCs everyday