

The three wireless “waves”

- **Wave #1: cellular telephony**
 - Still, biggest profit maker
- **Wave #2 : wireless Internet access**
 - Most Internet access on US campuses is wireless
 - Hot spots are rapidly proliferating in the US; Europe and Asia to follow soon
 - 2.5 G and 3G trying to keep up; competitive edge?
- **Wave #3: ad hoc wireless nets (now)**
 - Set up in an area with NO infrastructure; to respond to a specific, time limited need

Wireless Internet Options - Cellular

- **2.5 G**

- 1xRTT: CDMA based; 144Kbps
- GPRS: Time Division based (GSM); < 100Kbps
- Packet oriented; “always on”; per packet (instead of per call) charge

- **3G**

- UMTS: Wide Band CDMA from 384 Kbps to 2Mbps
- Integrates packet service with connection oriented service (voice, video, etc)

Wireless Internet Option: 802.11



- **Replacement for wired Ethernet**
- **Unlicensed spectrum (ISM)**
- **Several options and rates**
 - 802.11 b: 11, 5.5, 2, 1 Mbps; @ 2.4 GHz
 - 802.11 a up to 54 Mbps in 5.7 GHz band
 - 802.11 n, up to 100Mps with MIMO and OFDM technologies
- **Range**
 - Indoor 20 - 25 meters
 - Outdoor: 50 – 100 meters
- **Transmit power up to 100 mW**

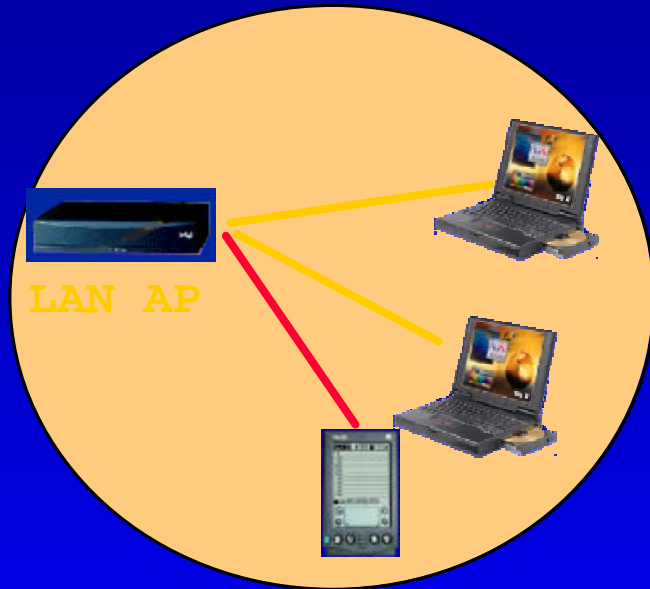
Wireless Internet options: Bluetooth



- **1998: Bluetooth SIG : Ericsson, IBM, Intel, Nokia, Toshiba**
- **A cable replacement technology**
- **Max rate 700Kbps @2.4 Ghz**
- **Range 10+ meters**
- **Single chip radio + baseband**
 - at low power (1mw) & low price point (\$5)
- **Convergence of 802.15 and Bluetooth in a single PAN standard**

Emerging Landscape

802.11



New developments are blurring the distinction

- 802.11b for PDAs
- Bluetooth for LAN access

Bluetooth

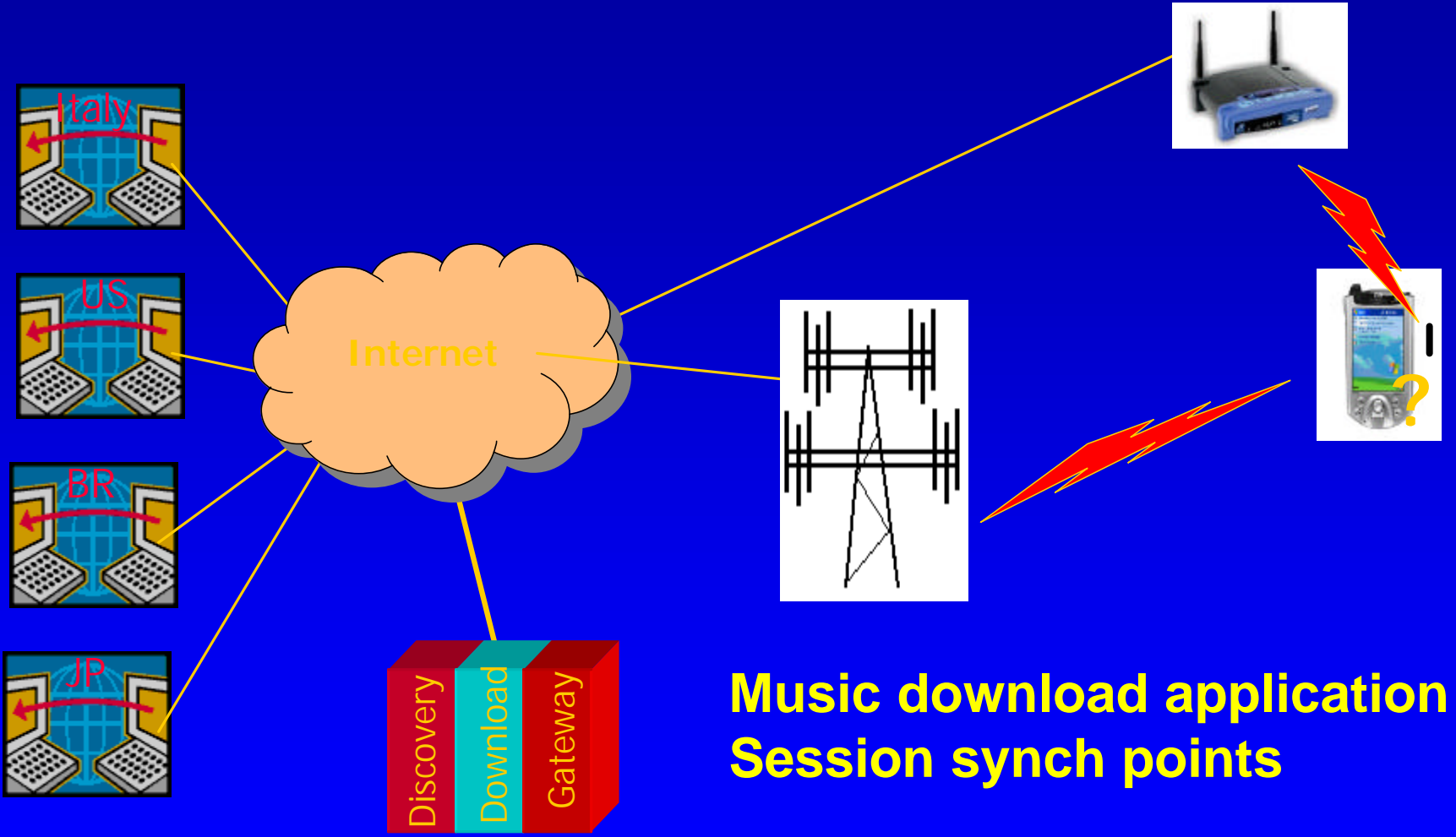


- Both 802.11 and Bluetooth will be used for access
- Complementary benefits

Which Internet access to choose?

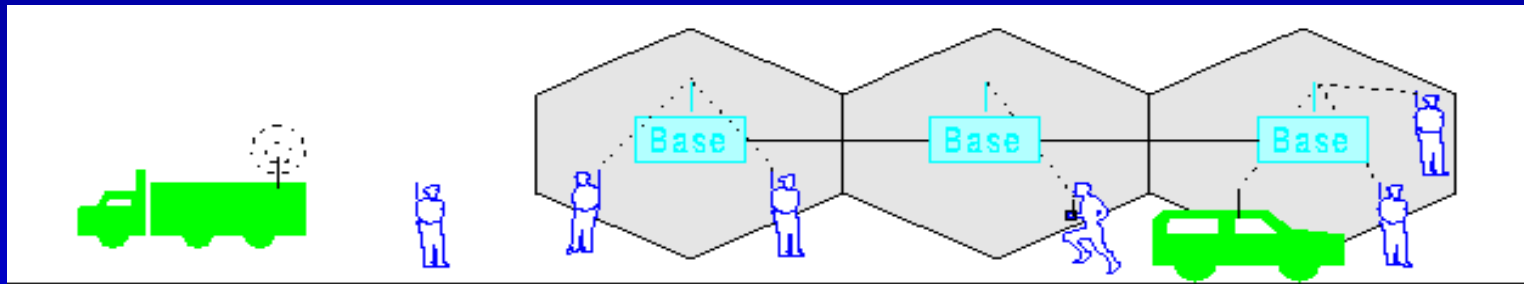
- **Most portables have multiple radio interfaces**
 - 802.11, Bluetooth and 1xRTT supported on PDAs
- **Dynamically select best access:**
 - Lowest connection charge
 - Best reception
 - Best power budget (must save battery power)
 - Suitable Qos
- **Challenges:**
 - Seamless handoff (network, session)
 - Rate content adaptation if data rates are different

“Vertical” Handoff between 802.11 and 1XRTT UCLA Project, 2003

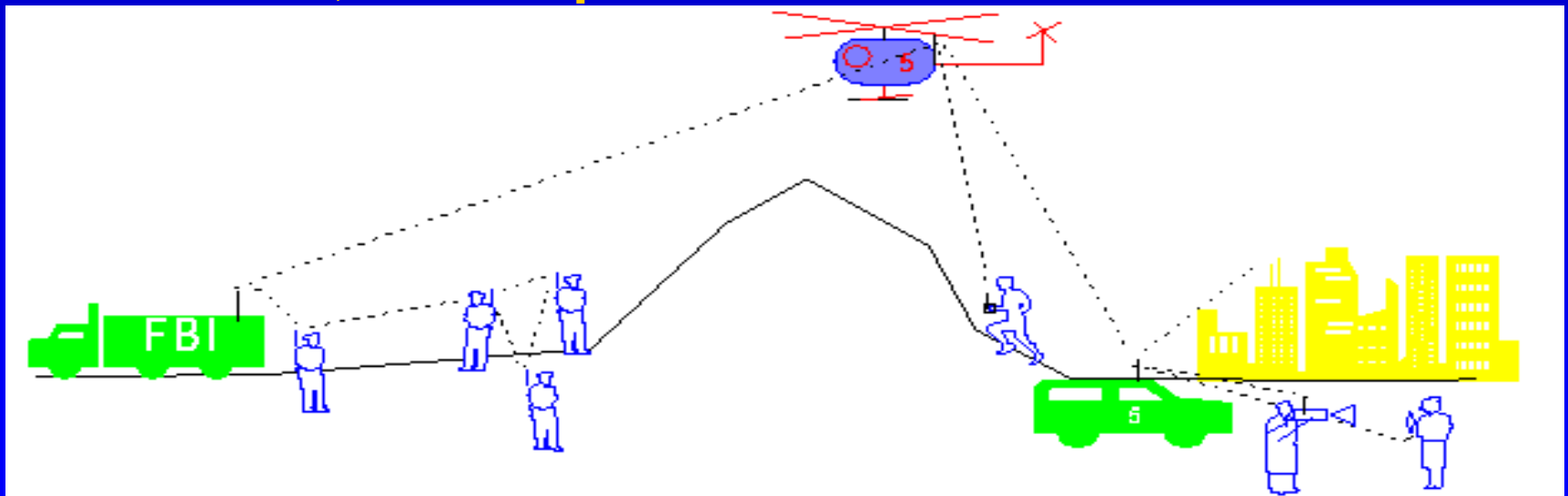


The 3rd Wave: Infrastructure vs Ad Hoc

Infrastructure Network (cellular or Hot spot)



Ad Hoc, Multihop wireless Network



General Ad Hoc Network Characteristics

- Instantly deployable, re-configurable (No fixed infrastructure)
- Created to satisfy a “temporary” need
- Node portability (eg sensors), mobility
- Limited battery power
- Multi-hopping (to save power, overcome obstacles, enhance spatial spectrum reuse, etc.)

Ad Hoc Network Applications

Military

- Automated battlefield

Civilian

- Disaster Recovery (flood, fire, earthquakes etc)
- Law enforcement (crowd control)
- Homeland defense
- Search and rescue in remote areas
- Environment monitoring (sensors)
- Space/planet exploration

Ad Hoc Network Applications (cont)

Commercial

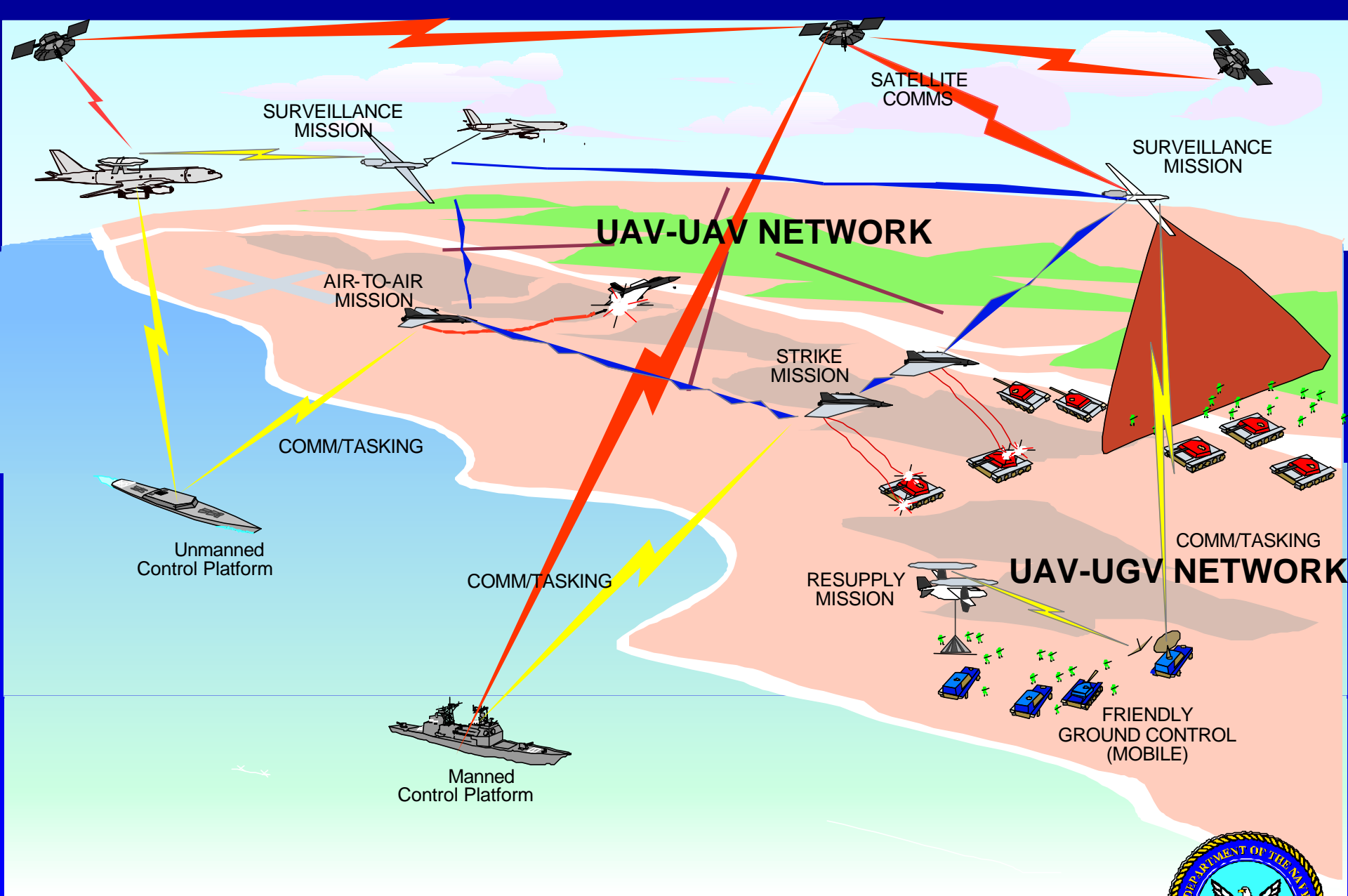
- Sport events, festivals, conventions
- Ad hoc collaborative computing (Bluetooth)
- Sensors on cars (car navigation safety); sensors on cows
- Networked video games at amusement parks, etc

Opportunistic ad hoc extensions (of Wireless Internet)

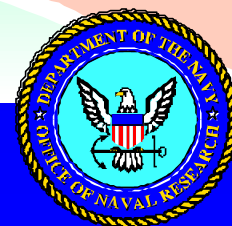
- Indoor W-LAN extended coverage
- Indoor network appliances (Bluetooth, Home RF)
- Hot spots (Mesh Networks)
- Campus, shopping mall, etc
- Urban grid

The Battlefield

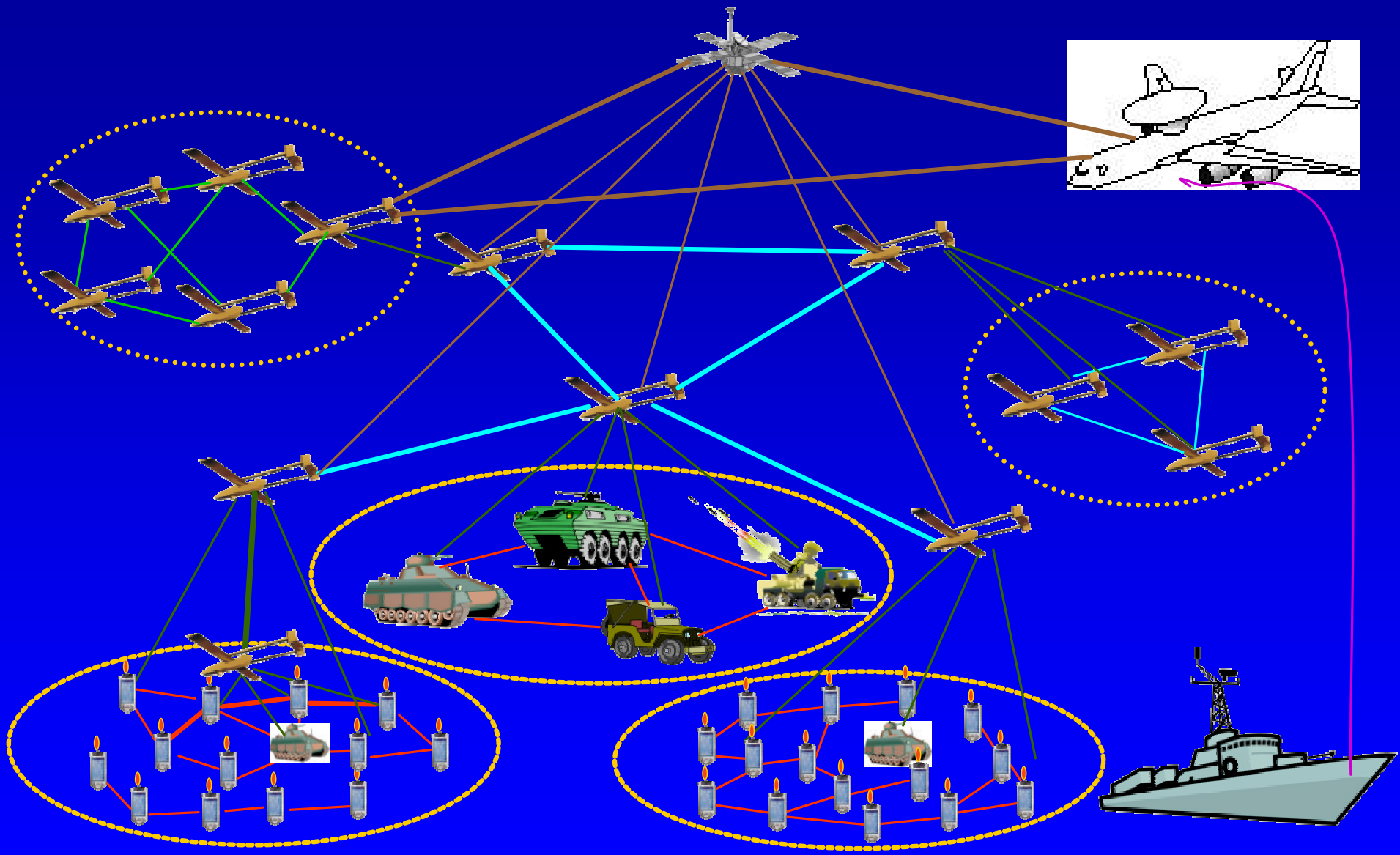
- DoD was first to understand the value of ad hoc networks for the automated battlefield
- In 1971 (two years after ARPANET), DARPA starts the Packet Radio project
- ONR (Office of Naval Research) sponsors **MINUTEMAN** - a 5 year program at UCLA (2000–2005)
- Goal: develop an “unmanned” , airborne ad hoc architecture



Minuteman: Algorithms and Protocols for Network of Autonomous Agents



The MINUTEMAN "Internet in the Sky"



Transferring Battlefield technology to civilian applications

Disaster recovery:

- Flood, mud slide, eruption, chemical or nuclear plant disaster
- Several rescue teams involved, with different functions
- Autonomous vehicle swarms (ground/airborne) are deployed (with sensors/actuators)
- Manned and unmanned teams cooperate in rescue
- “Ad Hoc networking” will be central to make the operation work