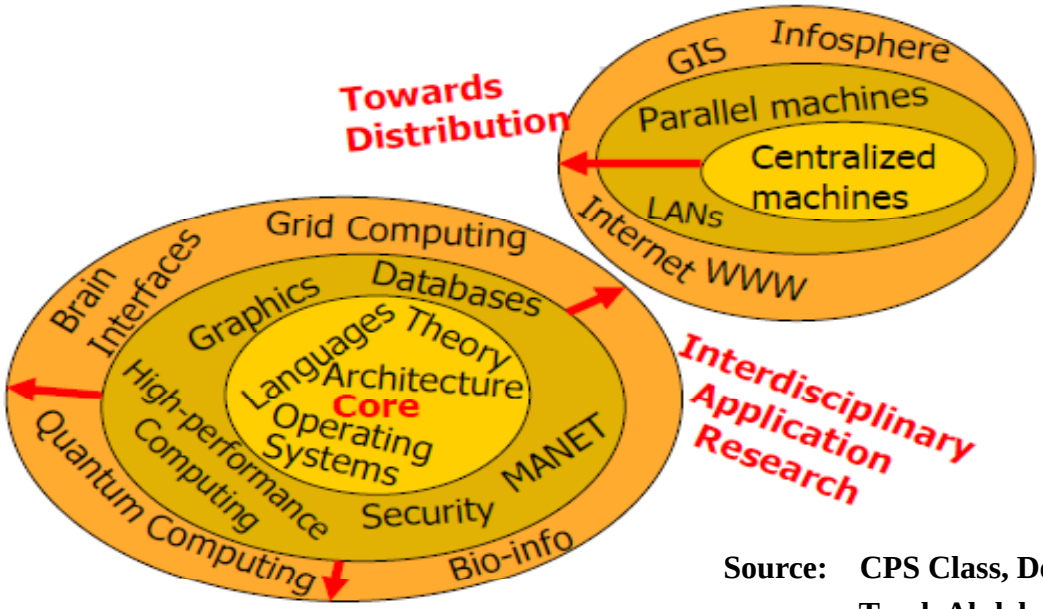
CPS (Cyber Physical System)

1. Current Trends of Computer Science
2. Cyber-Physical System (CPS)
3. Advanced Cyber-Physical System

Trends (1)

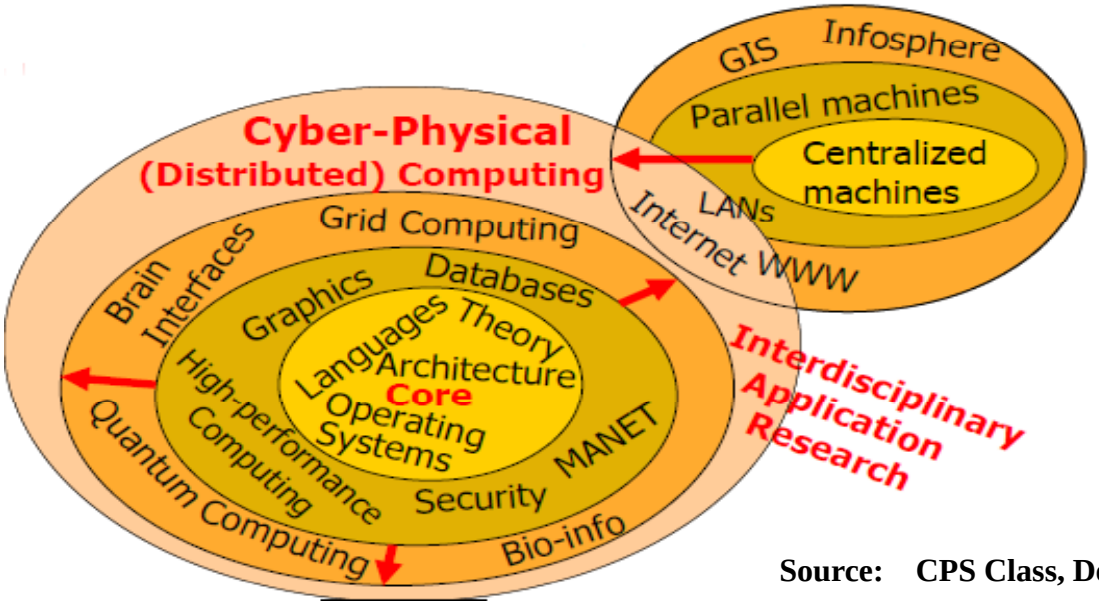
◎ **Where is Computer Science Research Going?**



Source: **CPS Class, Dept of CS, UIUC, Tarek Abdelzaher, 2011**

Trends (2)

◎ **Where is Computer Science Research Going?**



Source: **CPS Class, Dept of CS, UIUC, Tarek Abdelzaher, 2011**

CPS (Cyber Physical System)

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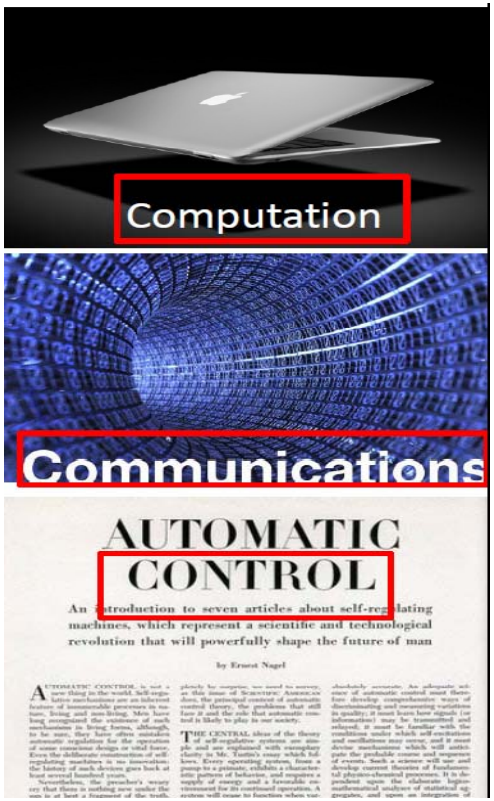
Cyber Systems

- **Cyber is**
  - More than just software
  - More than just networking
  - More than just embedded computing

- **Cyber implies the integration of**
  - Computation
  - Communication
  - Control



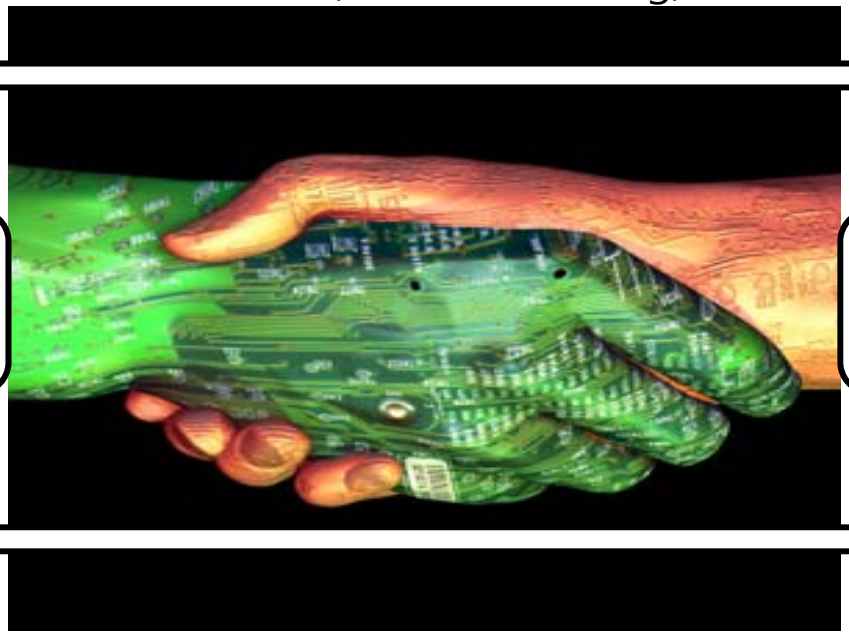
Physical Systems

◎ **Physical Systems means**

⊙ Natural and human-made systems governed by the laws of physics and operating in continuous time

What is CPS?

Real-time System (Control)
Network(Data Transferring)



Embedded System (Actuator)

Cyber World

Physical World

Embedded System(Sensor)

Data Store, Data Processing (Computation)

WSN(Sensing)
Network(Data Transferring)

What is CPS?

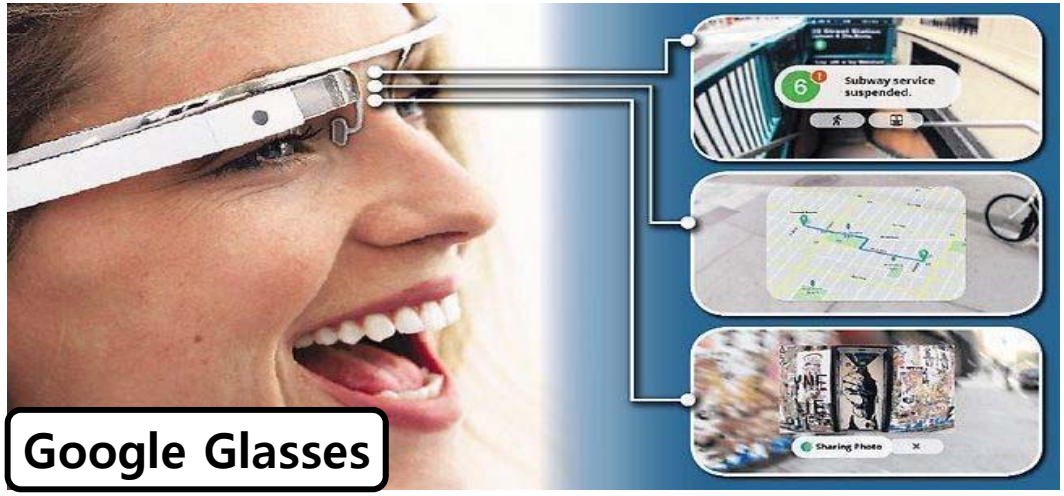
◎ Three definitions for CPS

- ⊙ System in which the cyber world and physical world are tightly integrated at all scales and levels (Wikipedia)
- ⊙ System that integrates computation and communication capabilities with monitoring and/or control entities in the physical world (S. Shankar Sastry, UC Berkeley)
- ⊙ CPS will transform how people interact with the cyber world just like the Internet transformed how we interact with one another. (NSF CPS Workshop)

What is CPS?

◎ Examples for the 1'st definitions

- ⊙ System in which the cyber and physical systems are tightly integrated at all scales and levels (Wikipedia)

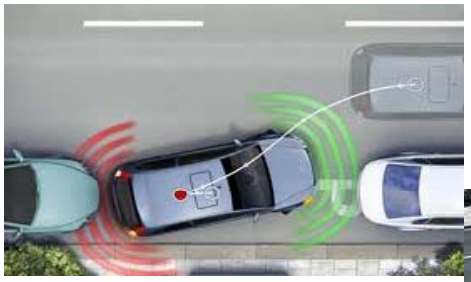


What is CPS?

◎ Examples for the 2'nd definitions

⊙ System that integrates computation and communication capabilities with monitoring and/or control entities in the physical world

(S. Shankar Sastry, UC Berkeley)



Auto parking system

데모 아우디

Monitoring
여유 공간, 앞차/뒷차/옆차 거리, 블록 및 벽까지 거리

Communication Media:
Embedded System Integrated (bus)

Computation:
핸들 각도, 전진, 후진, 속도 등

Control:
핸들, 액셀, 브레이크

What is CPS?

◎ Examples for the 3'rd definitions

- ⊙ CPS will transform how we interact with the cyber world just like the Internet transformed how we interact with one another. (NSF CPS Workshop)

Physical world

Cyber world

Golf Game

CPS world

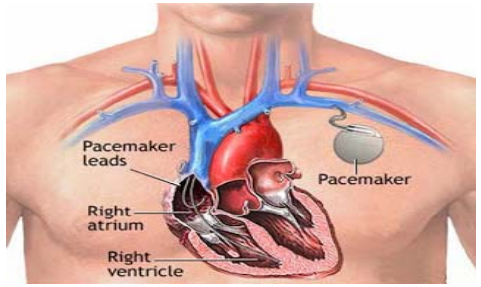
Examples

- Common applications of CPS typically fall under sensor-based systems and autonomous systems.
  - Example
    - Intervention (e.g., collision avoidance)
    - Precision (e.g., robotic surgery and nano-level manufacturing)
    - Operation in dangerous or inaccessible environments (e.g., search and rescue, firefighting, and deep-sea exploration)
    - Coordination (e.g., air traffic control, war fighting)
    - Efficiency (e.g., zero-net energy buildings)
    - Augmentation of human capabilities (e.g., healthcare monitoring and delivery).

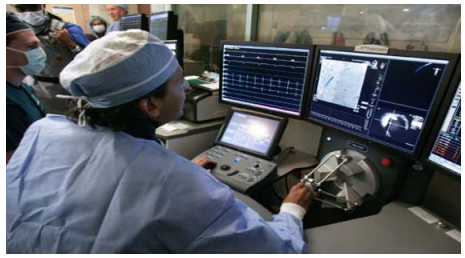
Examples

◎ Other CPS Examples

- **Home care: monitoring and control**
  - Pulse oximeters, blood glucose monitors, infusion pumps (insulin), accelerometers (falling, immobility), wearable networks (gait analysis), prosthetics…
- **Operating Room of the Future (Goldman)**
  - Closed loop monitoring and control; multiple treatment stations, plug and play devices; robotic microsurgery (remotely guided?)
  - System coordination challenge



pacemaker

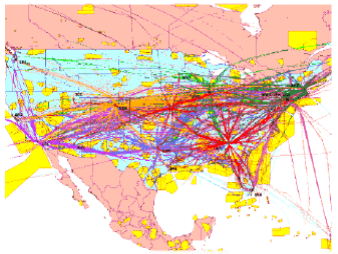


Remote Robotic surgery

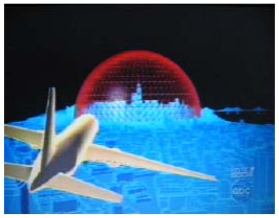
Examples

Other CPS Examples

- Aviation Industry
  - Air traffic control systems
    - Systems to prevent collisions, organize and expedite the flow of traffic, and provide information and other support for pilots when able
  - Automatic pilot avionics
    - Control key systems of the plane and its flight by using electronics for communications, navigation, collision avoidance and weather
    - Many aircraft also have collision avoidance systems, which provide additional safety by warning pilots when other planes get too close



Air traffic control



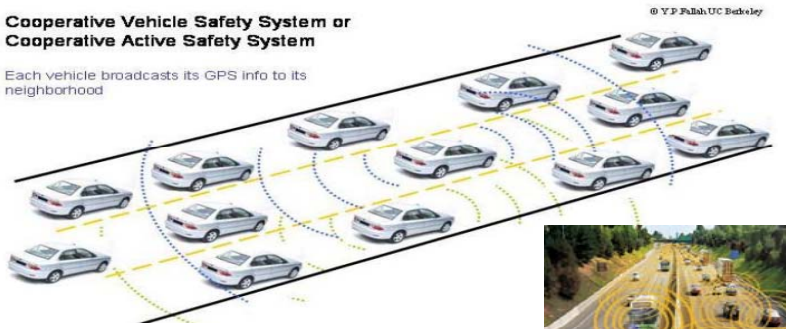
Automatic pilot avionics

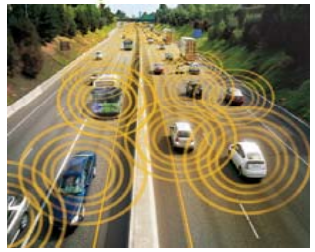
Examples

Other CPS Examples

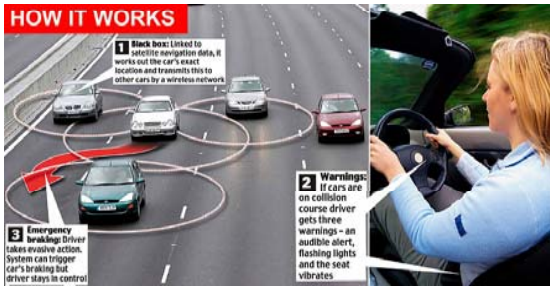
Intelligent Transportation Systems (ITSs)

- Safety: vehicles broadcast their physical state information over a wireless network to allow their neighbors to track them and predict possible collisions, trigger speed-limit reminder, accident warning
- Traffic information: share information on the traffic on-road for traffic congestion alarm, get map updates
- Entertainment: search for places of interest via the Internet

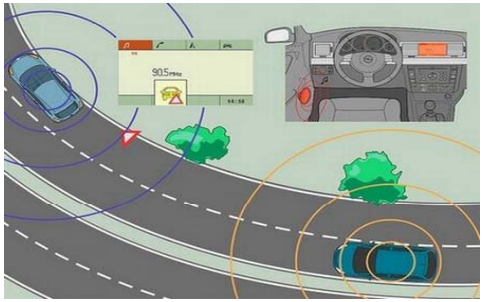




Traffic information sharing



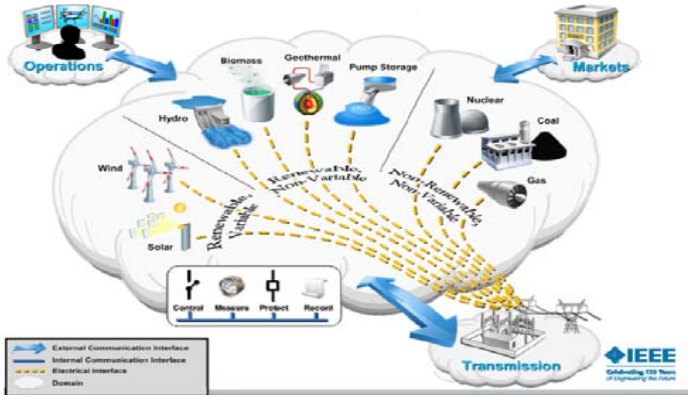
Safety information

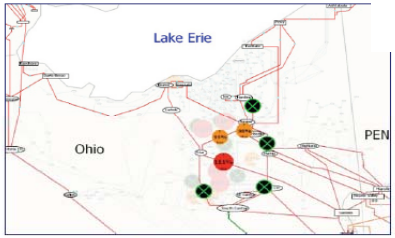


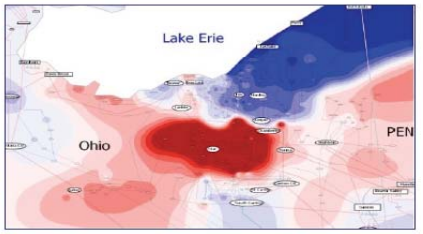
Examples

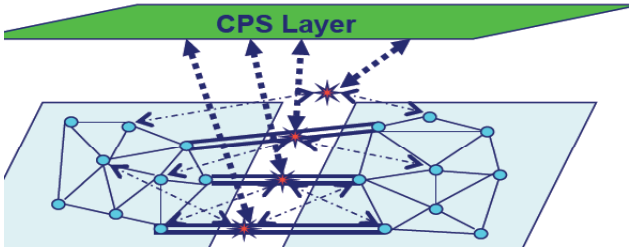
◎ Other CPS Examples

- ⊙ Smart Power Grid
  - ⊙ 스마트그리드는 송전망과 배전망에 정보기술을 접목하여 양방향 데이터통신이 가능하도록 함으로써 전력 사용 효율성을 높이고 나아가 전력사용을 줄여 온실가스배출을 억제하는 것을 목표로 삼고 있다.
  - ⊙ Current picture
    - ⊙ Reactive equipment protection
    - ⊙ Power outage over the world
      - ⊙ 25 july 2010, washingtol D.C. backout
      - ⊙ 22 March 2010, Malta, national-wide blackout









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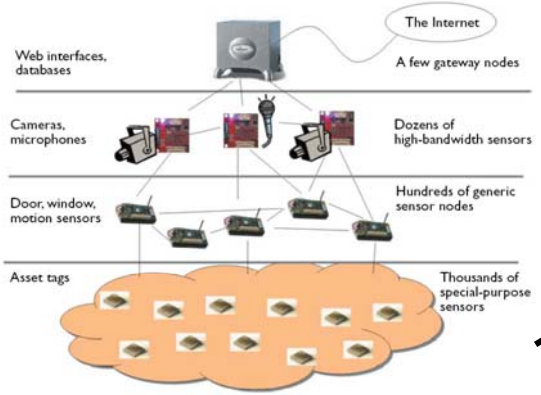
3. Advanced Cyber-Physical System

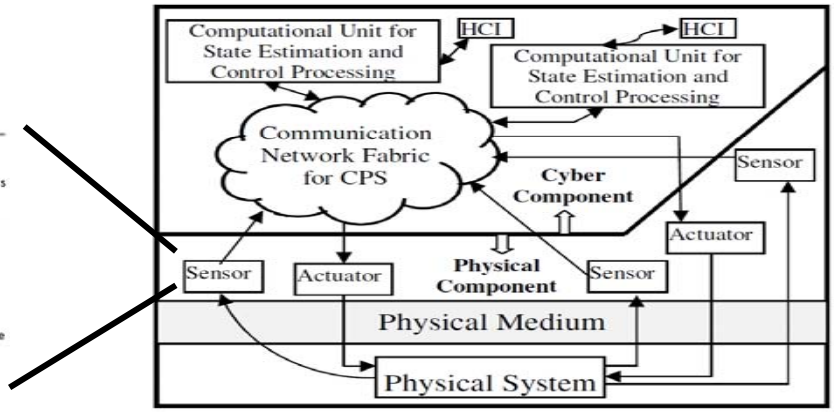
S INSTITUTE OF TECHNOLOGY

What is Advanced CPS

- **What is the Advanced CPS**
  - **Co working with many WSNs**
  - **Big data processing**
  - **More accurate decision**
  - Controlling actuator with a distributed real-time manner

Cf.) 일반적인 CPS의 예: 로봇

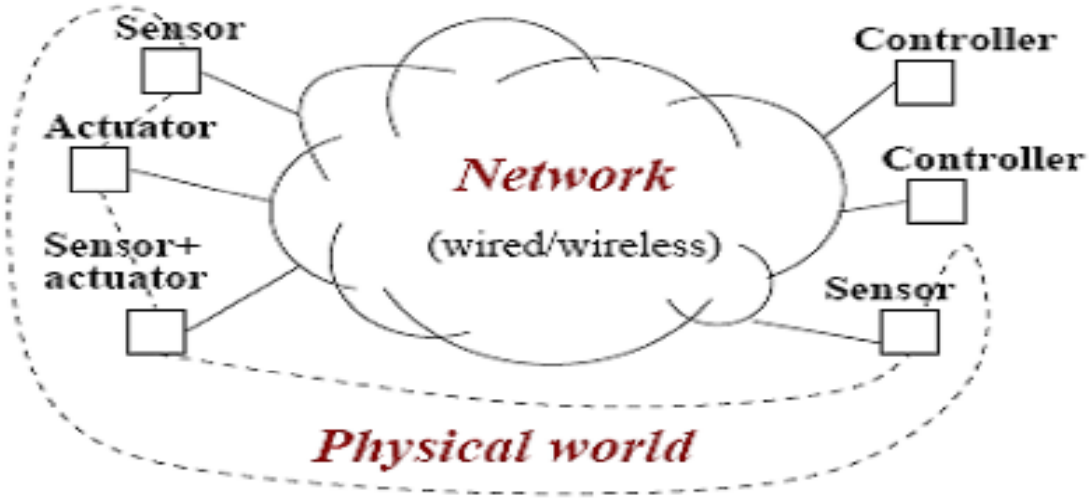




Source: "Cyber-Physical Systems: A confluence of Cutting Edge Technology Streams", ICACC'11, 2011.

What is Advanced CPS

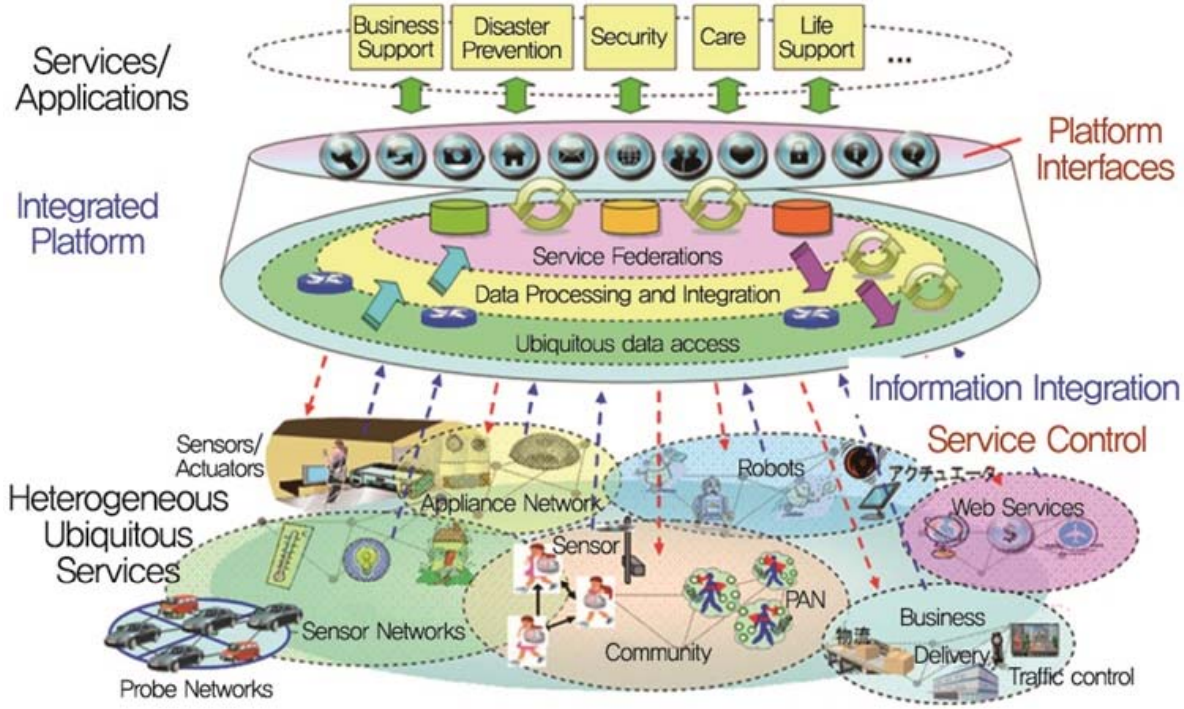
◎ **Big Picture of Advanced CPS**



Source: VincenzoLiberatore, "Networked Cyber-Physical Systems: An Introduction", 2007

What is Advanced CPS

◎ Big Picture of Advanced CPS



What is Advanced CPS

- **Advance CPS Vs. CPS**

  System with sensor, computer and actuator
  (ex. Robot)

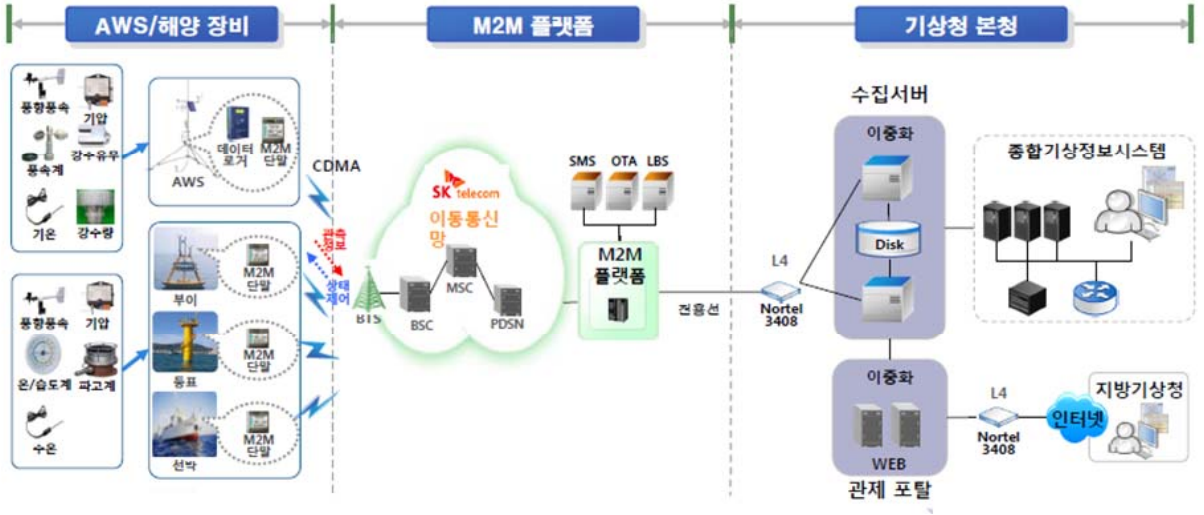
  - A more holistic/interdisciplinary approach
  - More distribution
  - Less structure
  - Interactions between multiple autonomous domains
  - Increasingly open systems

Generally the term of "CPS" means advance CPS.

Examples

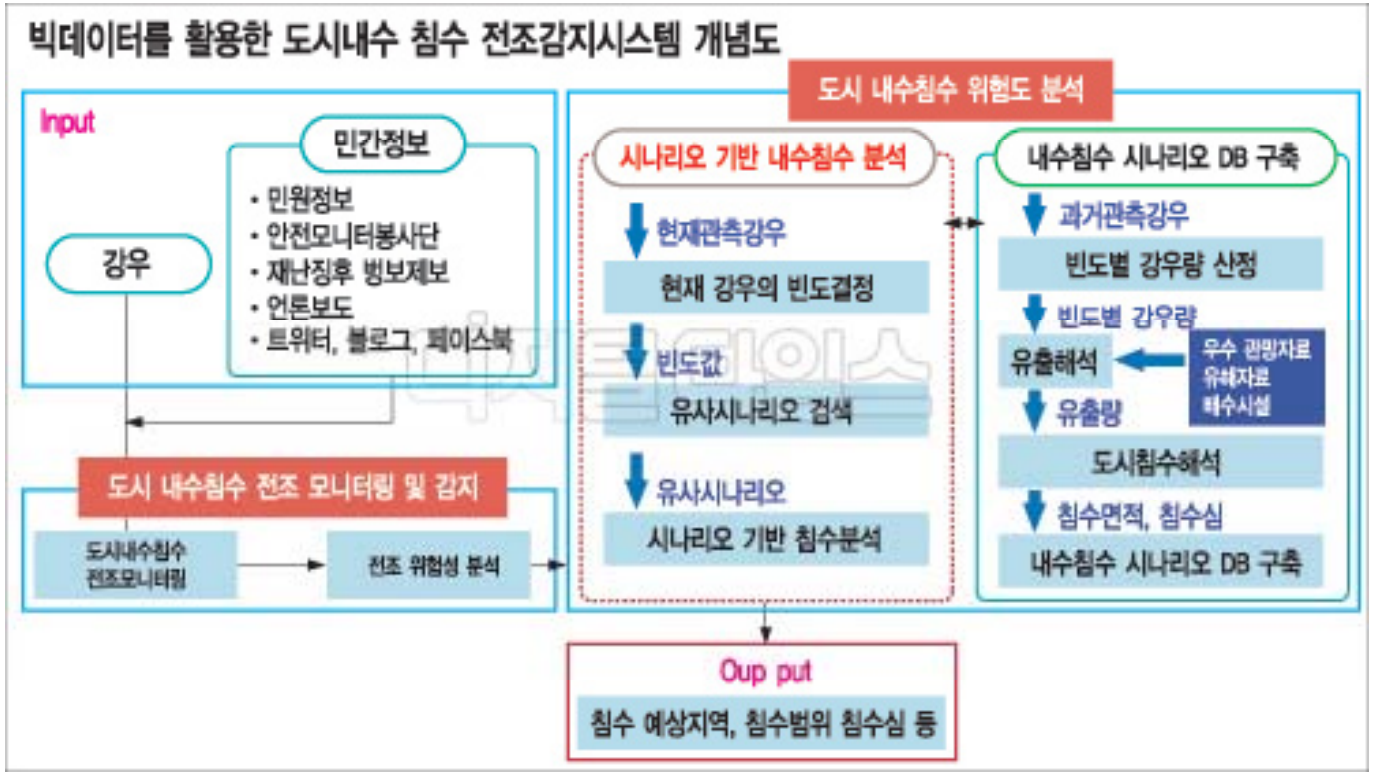
기상예측시스템

- ✓ 1분 수집자료 실시간 전송
- ✓ 데이터 로거/단말 원격제어
- ✓ 원격 F/W 업그레이드
- ✓ GPS 연동 시각 동기화



- CDMA 모뎀을 통한 기상 자료 수집 및 전송
- 신뢰성 있는 데이터 송수신
- 양방향 통신 지원
- 원격제어 기능
- 기상자료 통합수집/관측
- 수집 자료 COMIS 전송

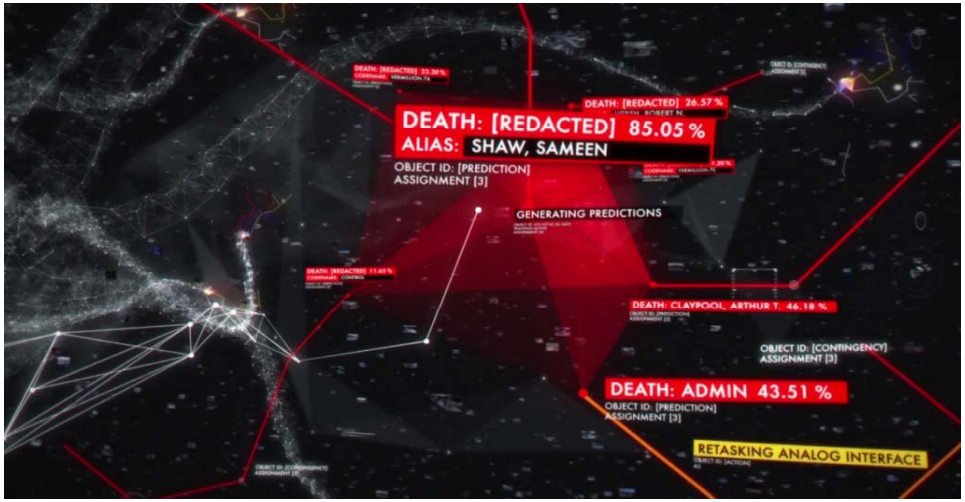
Examples


빅데이터를 활용한 도시내수 침수 전조감지시스템 개념도
Input
민간정보
• 민원정보
• 안전모니터봉사단
• 재난징후 빙보제보
• 언론보도
• 트위터, 블로그, 페이스북
강우
도시 내수침수 전조 모니터링 및 감지
도시내수침수 전조모니터링
전조 위험성 분석
도시 내수침수 위험도 분석
시나리오 기반 내수침수 분석
현재관측강우
현재 강우의 빈도결정
빈도값
유사시나리오 검색
유사시나리오
시나리오 기반 침수분석
내수침수 시나리오 DB 구축
과거관측강우
빈도별 강우량 산정
빈도별 강우량
유출해석
우수 관망자료
유해자료
배수시설
유출량
도시침수해석
침수면적, 침수심
내수침수 시나리오 DB 구축
Oup put
침수 예상지역, 침수범위 침수심 등

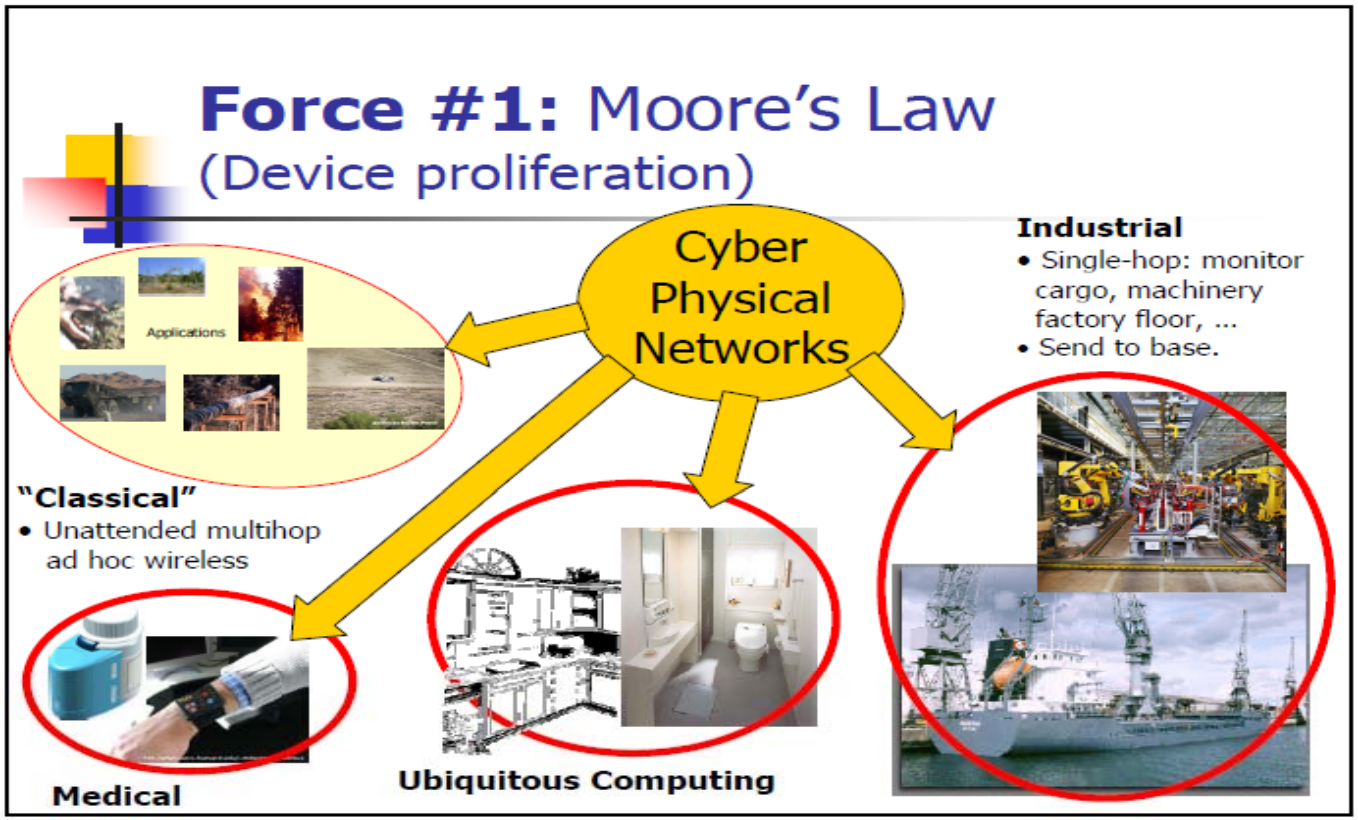
Examples

◎ 예) 살인 예측 시스템

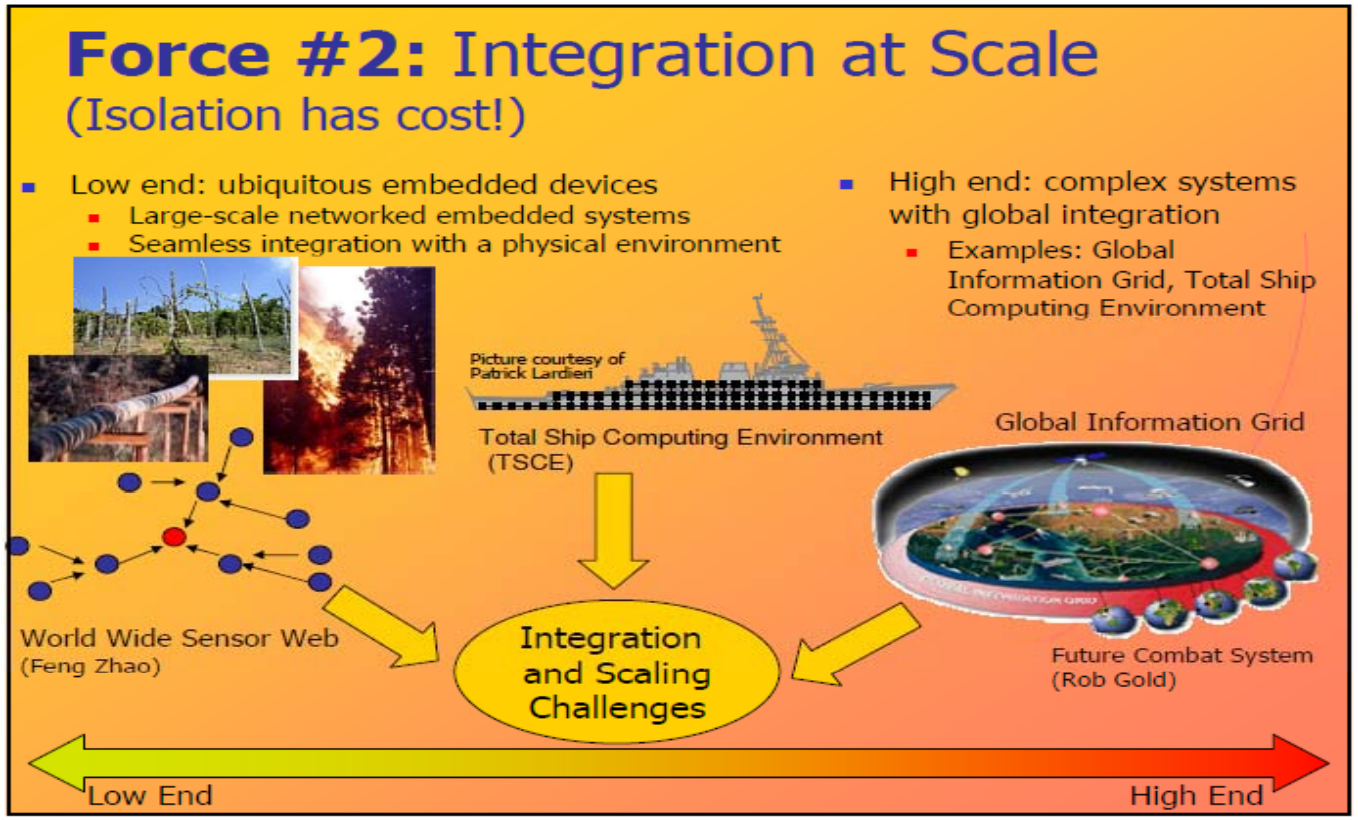
⊙ 드라마: Person of Interest



Why Advanced CPS?

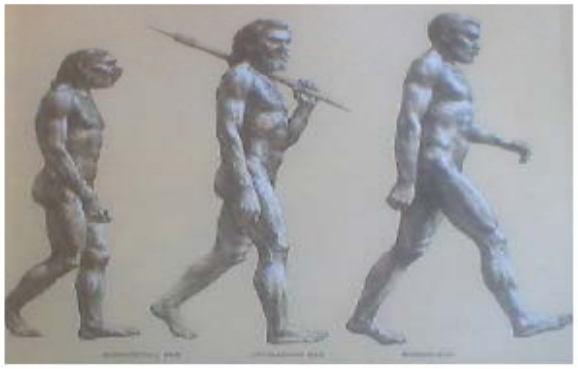


Why Advanced CPS?



Why Advanced CPS?

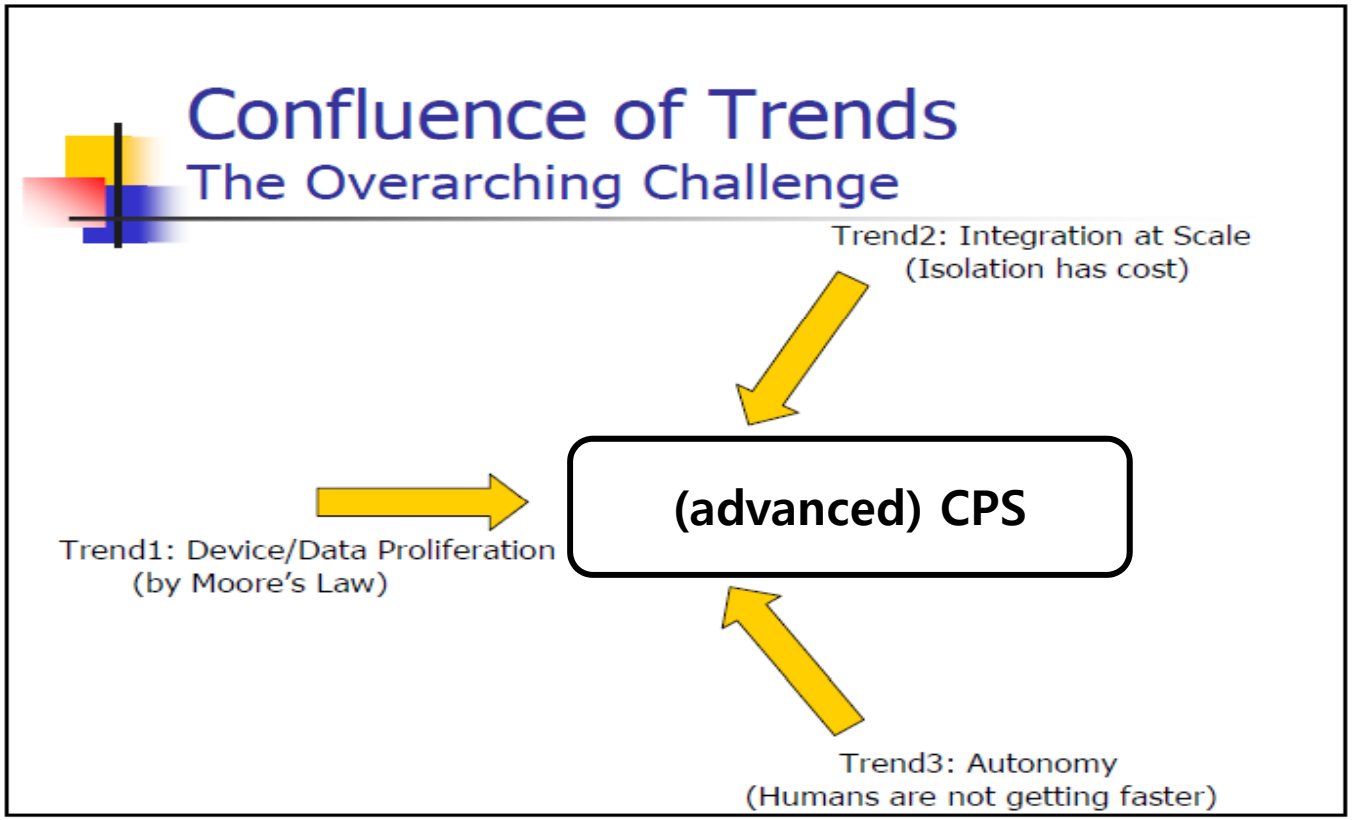
Force #3: Biological Evolution



- **It's too slow!**
  - The exponential proliferation of data sources (afforded by Moore's Law) is ***not*** matched by a corresponding increase in human ability to consume information!

→ Increasing autonomy (human out of the loop), direct world access

Why Advanced CPS?



Characteristics of Advanced CPS

A New Research Area

- Artificial intelligence
  - Can machines think?
  - By A. Turing in “Computing Machinery and Intelligence”, 1950
- Ubiquitous Computing
  - Computers everywhere
  - By Mark Weiser, XEROX PARC, 1990
- Pervasive Computing
  - 6As Model, The “authorized access to anytime-anywhere-any device-any network-any data”
  - Industry vision (1999, IBM, etc.)
- Cyber-Physical Systems
  - Computation and networking integrated with physical processes

Characteristics of Advanced CPS

Research Challenges

- Build the interface between the cyber world and the physical world?
- Why this is hard:
  - No clear boundaries between cyber and physical worlds.
  - Boundaries are always changing.
  - No perfect digitization of the continuous world
  - Inpredicable complex systems
  - Essentially multi-disciplinary

Characteristics of Advanced CPS

Multi-disciplinary

- Sensing technologies
- Distribute computing and networking
- Real-time computing
- Control theory
- Signal processing
- Embedded systems

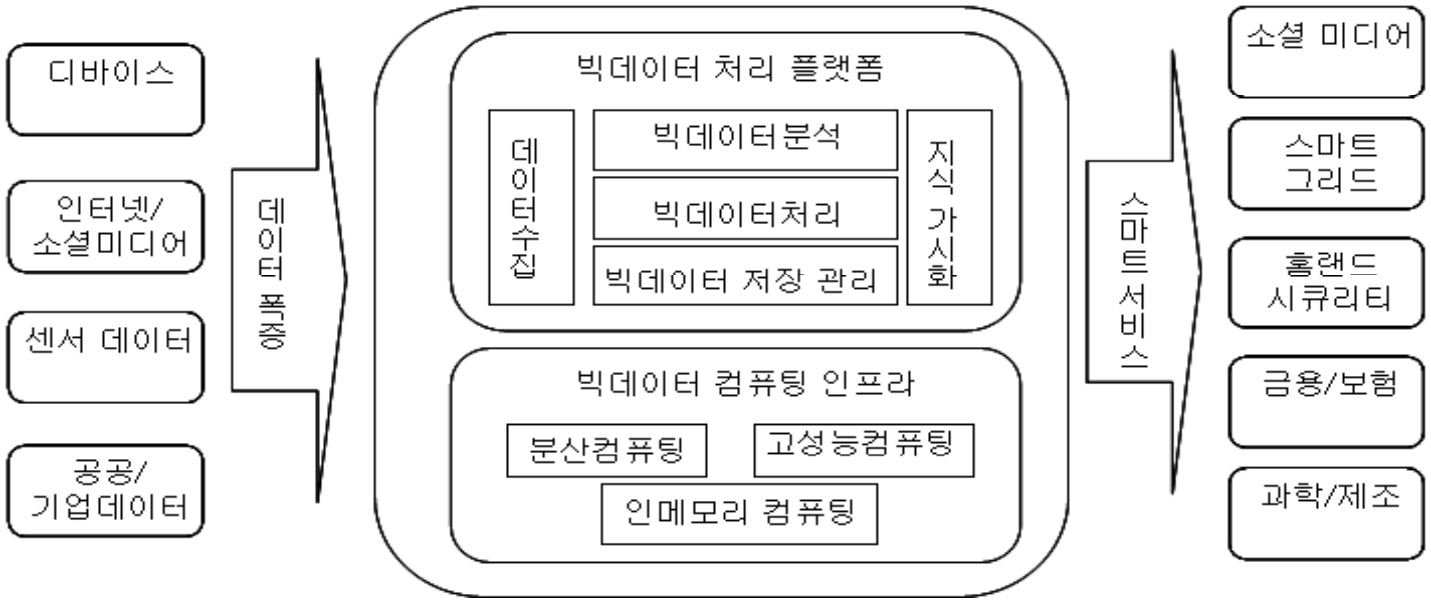
Characteristics of Advanced CPS

Current Research Issue

- 1. Sensing
  - Context from multiple sensors
  - Social sensing (even better, social + sensor)
  - Distributed group sensing
  - Crowdsourcing / citizen science
- 2. Output
  - Precision augmented reality
  - Unique uses of augmented reality beyond geolocation
  - Real-time control
- 3. Network
  - Power efficiency
  - Interoperability between the heterogeneous networks
  - Network QoS & Comm. Middleware
- 4. Big Data Processing
- 5. Validation & Verification (e.g. simulation, formal models, etc.)

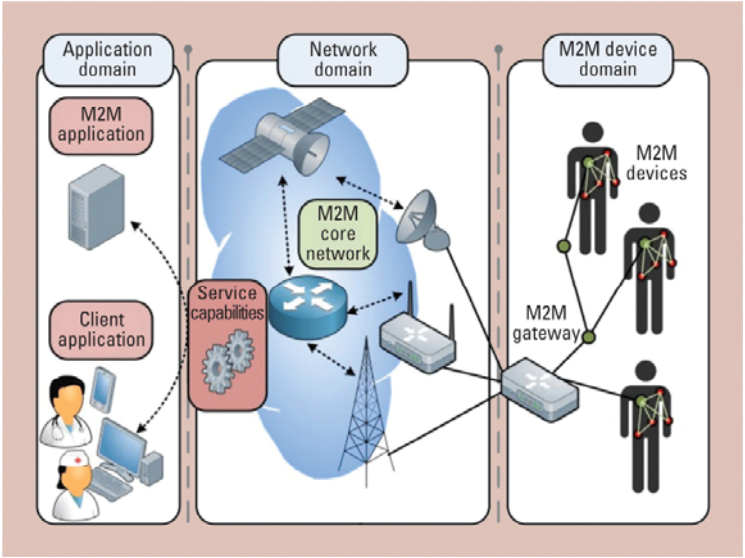
cf.) BigData

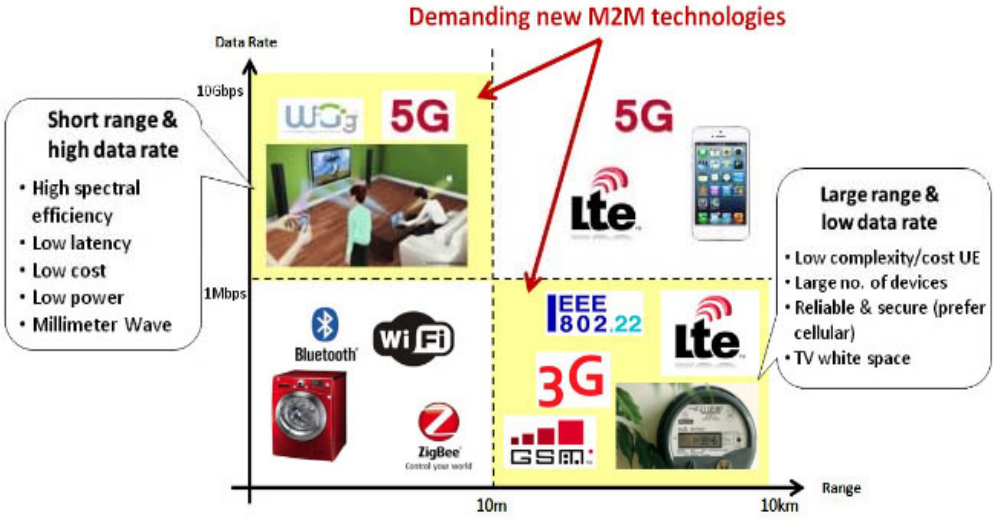
◎ **BigData 기술은 advanced CPS의 정확도와 신뢰성을 향상시켜주는데이터 처리/저장/분석 측면의 기반기술이다.**



cf) M2M 또는 D2D

◎ M2M 또는 D2D는 디바이스끼리의 통신기술에 초점을 둔 기술로써, advanced CPS를 구현하기 위한 네트워크 측면의 기반기술임



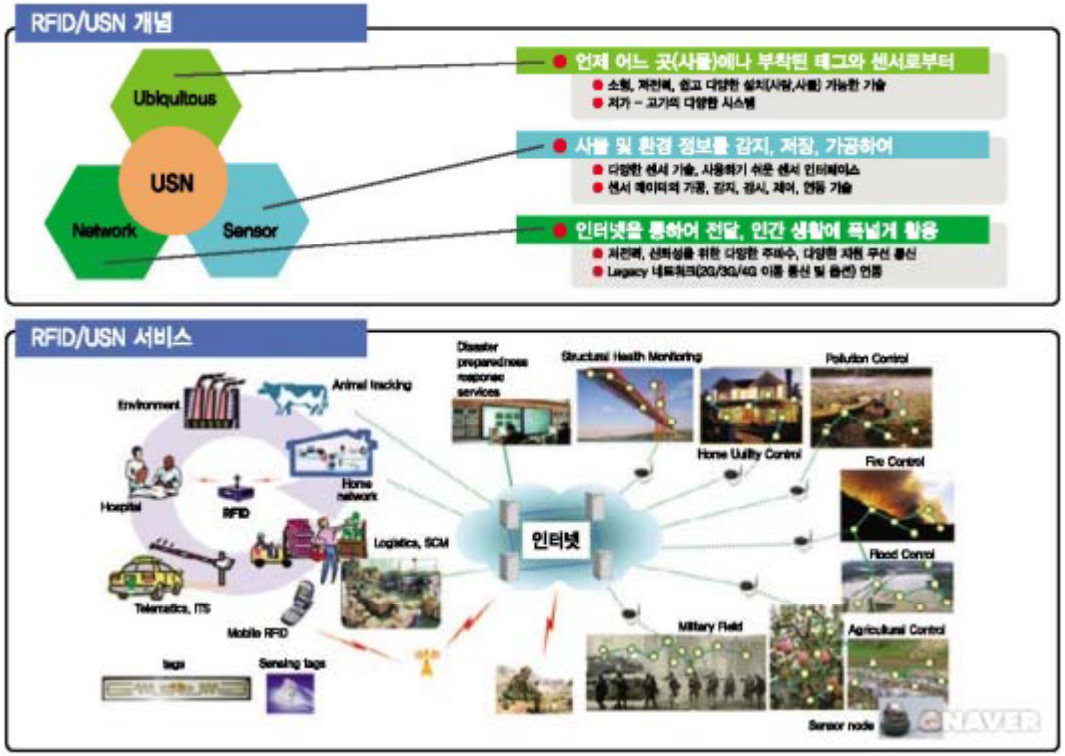


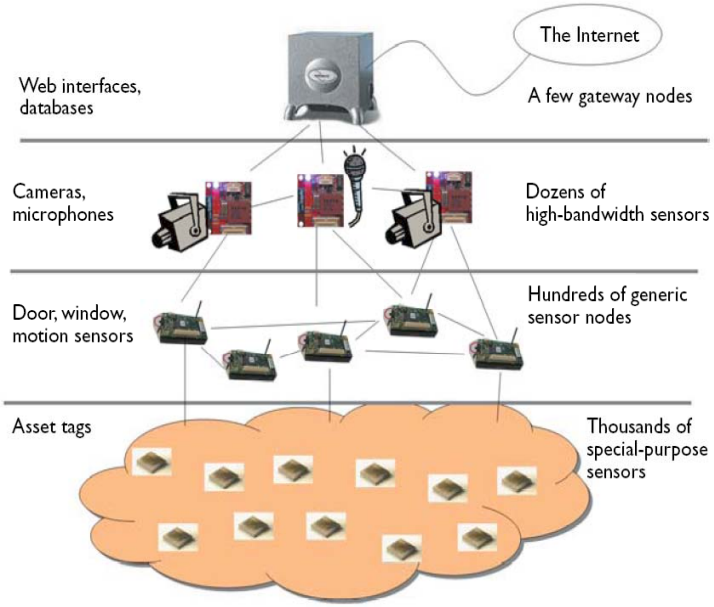
cf) IoT (Internet of Things)

◎ IoT는 advacend CPS와
거의 같은 의미로 통용됨.

cf) USN

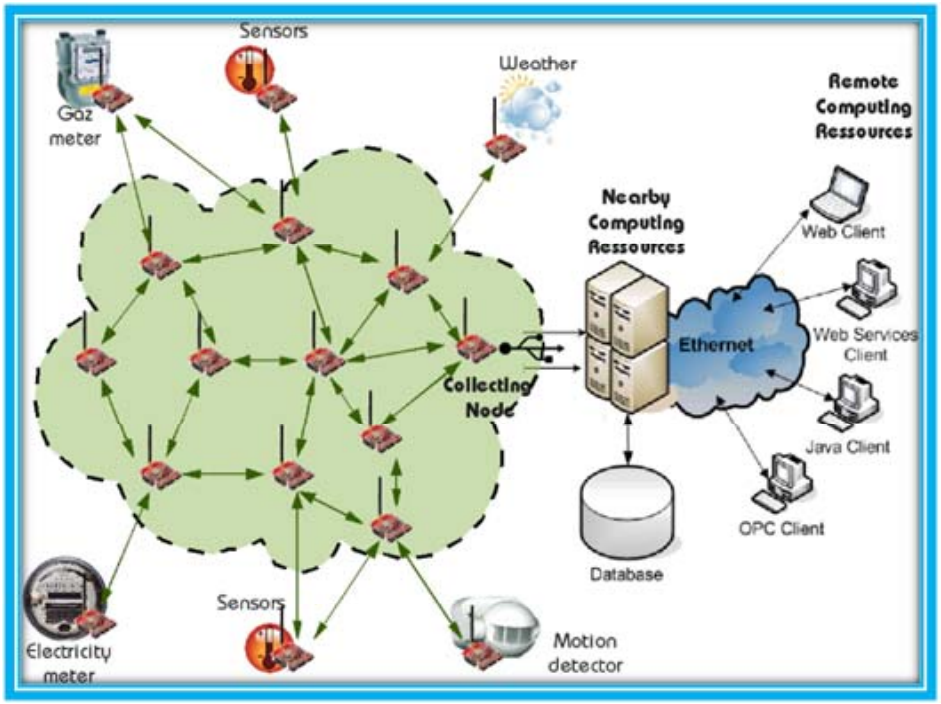
◎ USN은 advanced CPS 의 데이터 수집부분에 해당된다.





cf) WSN ← 본 과목의 주된 관심사

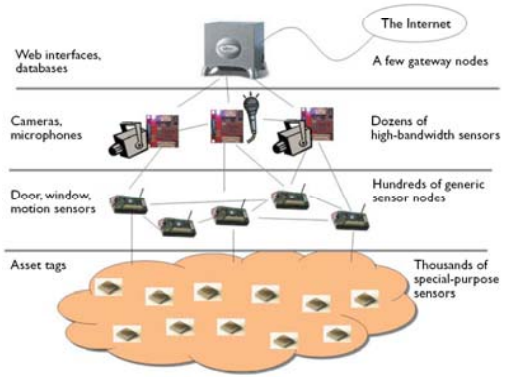
◎ WSN은 USN의 다양한 종류의 센서들 중 무선으로 연결된 저가의 소형센서들로 이루어진 네트워크를 말한다.

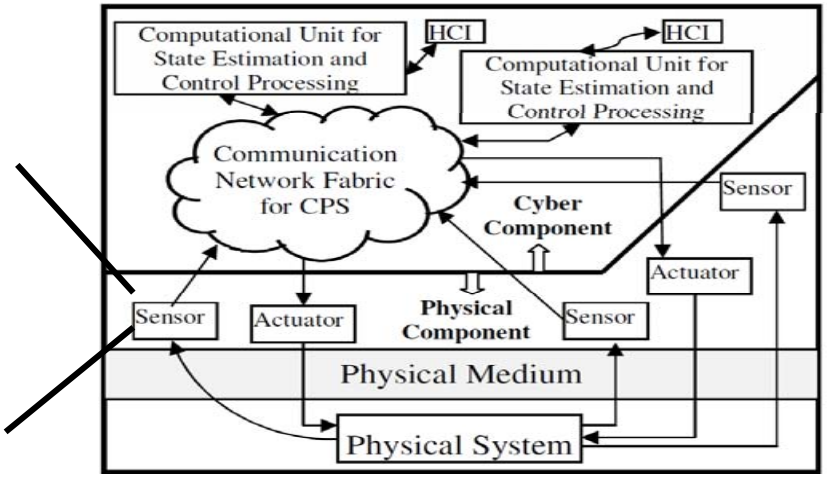


WSN in CPS

CPS -> human

- **USN** -> sensory organ, Knowledge, experience,
  - 그 중 **WSN**은 neural network 의 역할 (각 센서는 neuron의 역할)
- **Actuator** -> muscular organ, personal coach
- **Cloud computing with big-data** -> brain
- **Network infra** -> neural network / muscle-control nerves



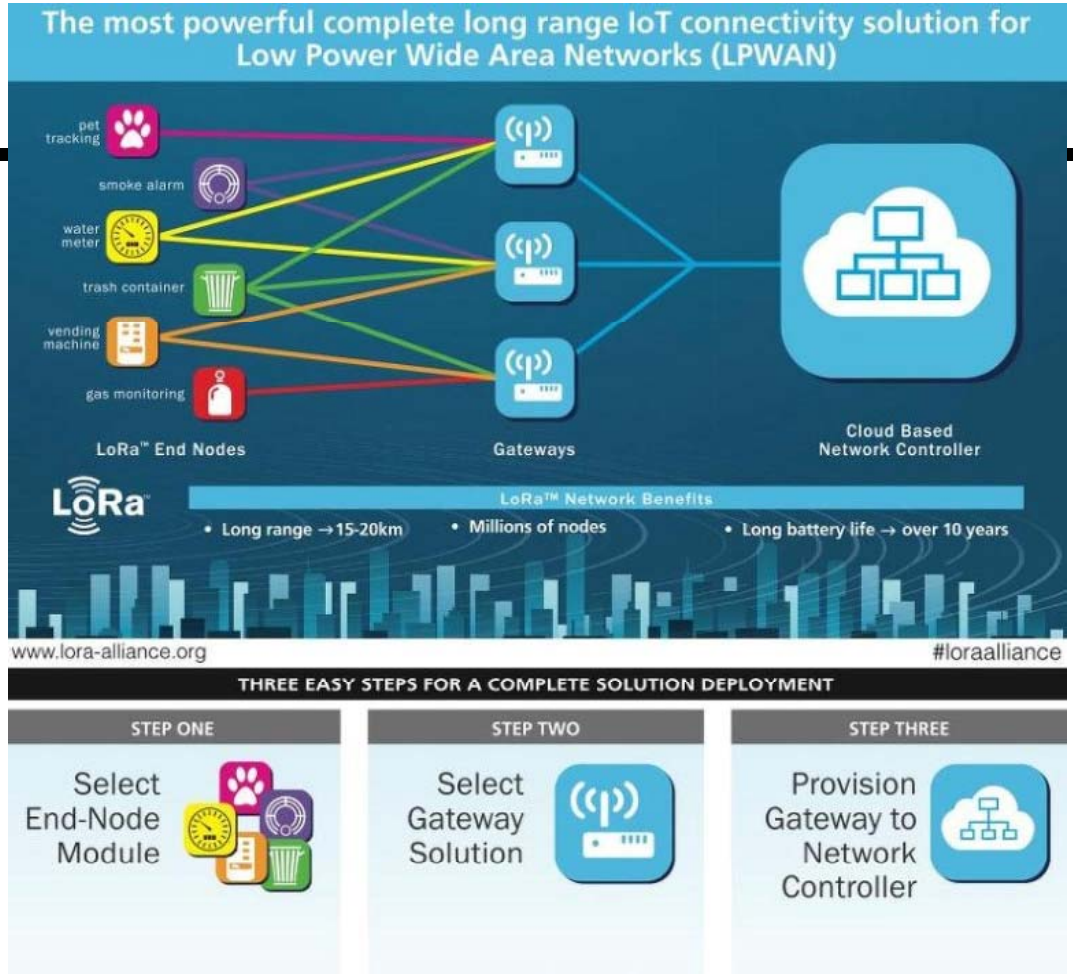


참고) IoT 통신 기술

사물인터넷의 범위 및 요소 기술

- **센서**
  - ✓ 실제 데이터를 수집하는 최 접점
- **임베디드 단말**
  - ✓ 수집된 정보를 취합 및 전송
- **네트워크**
  - ✓ 근거리: 주로 센서와 임베디드 단말 통신
  - ✓ 원거리: 단말과 서버 사이의 통신
- **보안**
  - ✓ 데이터 유출, 외부 침입, 사생활 침해 등 방지
- **미들웨어**
  - ✓ Event Processing: 대량 데이터에 대한 1차 패턴 분석
  - ✓ Messaging: 데이터의 전송 보장
- **클라우드 컴퓨팅**
  - ✓ 효율적인 End-to-End IoT 플랫폼 구축
- **데이터 처리 및 분석**
  - ✓ 빅데이터: 센서에서 수집된 비정형, 대량 데이터 처리
  - ✓ DW/BI: 데이터로부터 의미 있는 비즈니스 정보 추출

18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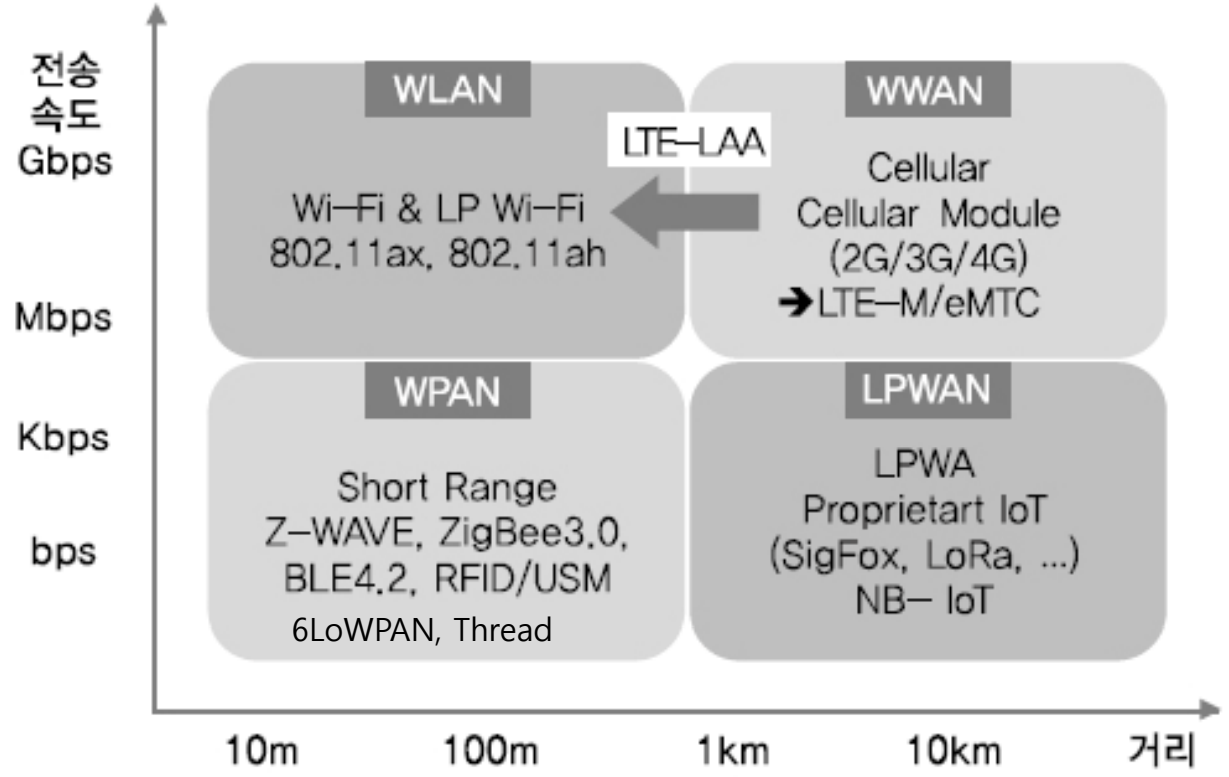
Select End-Node Module
STEP TWO
Select Gateway Solution
STEP THREE
Provision Gateway to Network Controller



IoT의 무선 커넥티비티

구분	저전력 IoT 전용망 기술			기존 데이터망 기술
	로라(LoRa)	NB-IoT	SigFox	LTE-M (Cat.1)
주파수 대역	▪ 비 면허 대역 (920MHz)	▪ LTE 대역 내	▪ 비 면허 대역 (920MHz)	▪ LTE 대역 내
통신 규격 표준화	▪ LoRa Alliance 표준	▪ 3GPP LTE 표준화 진행 중 (Rel.13, ~'16.2Q)	▪ ETSI (유럽 표준)	▪ 3GPP LTE ▪ 기존 LTE 통신 중 가장 속도가 낮은 규격
셀 커버리지	▪ ~10km	▪ ~10km	▪ ~10km	▪ ~5km
전송 속도	▪ ~5.4kbps	▪ ~수백kbps	▪ 100~600bps	▪ 10Mbps 이하
Global 상용 현황	▪ 기상용화	▪ '17년 예상	▪ 기상용화	▪ 기상용화
Eco-system	▪ Open ▪ Global 다수 업체 참여	▪ Open ▪ Global 다수 업체 참여	▪ SigFox社 독점	▪ Open ▪ Global 다수 업체 참여
모뎀 가격	▪ 약 5$	▪ 5~10$		▪ 약 20$

IoT 플랫폼

- HW 플랫폼
  - 인탤의 애디슨보드와 라즈베리파이, 아두이노 우노, 삼성의 아틱, TI의 블릭 등 여러 하드웨어 오픈소스 프랫폼
- SW플랫폼 : OS + 통신
  - 오픈소스 OS로는 아두이노 스캐치, MS의 윈10 IOT Core, 삼성의 타이젠, 구글의 브릴로(안드로이드 개선)
  - 크로스 통신 플랫폼 (다양한 주변 제품들끼리 상호작용)
    - 구글 위브, 퀄컴 올조인 등
      - wifi, Thread 등 다양한 통신 프로토콜을 안정적이고 작은 크기로 지원.