Mobile and social sensing systems

During one of his talks in 1991, Mark Weiser outlined a set of principles describing forthcoming computing.

Ubiquitous computing names the third wave in computing, just now beginning.

First were mainframes, each shared by lots of people.

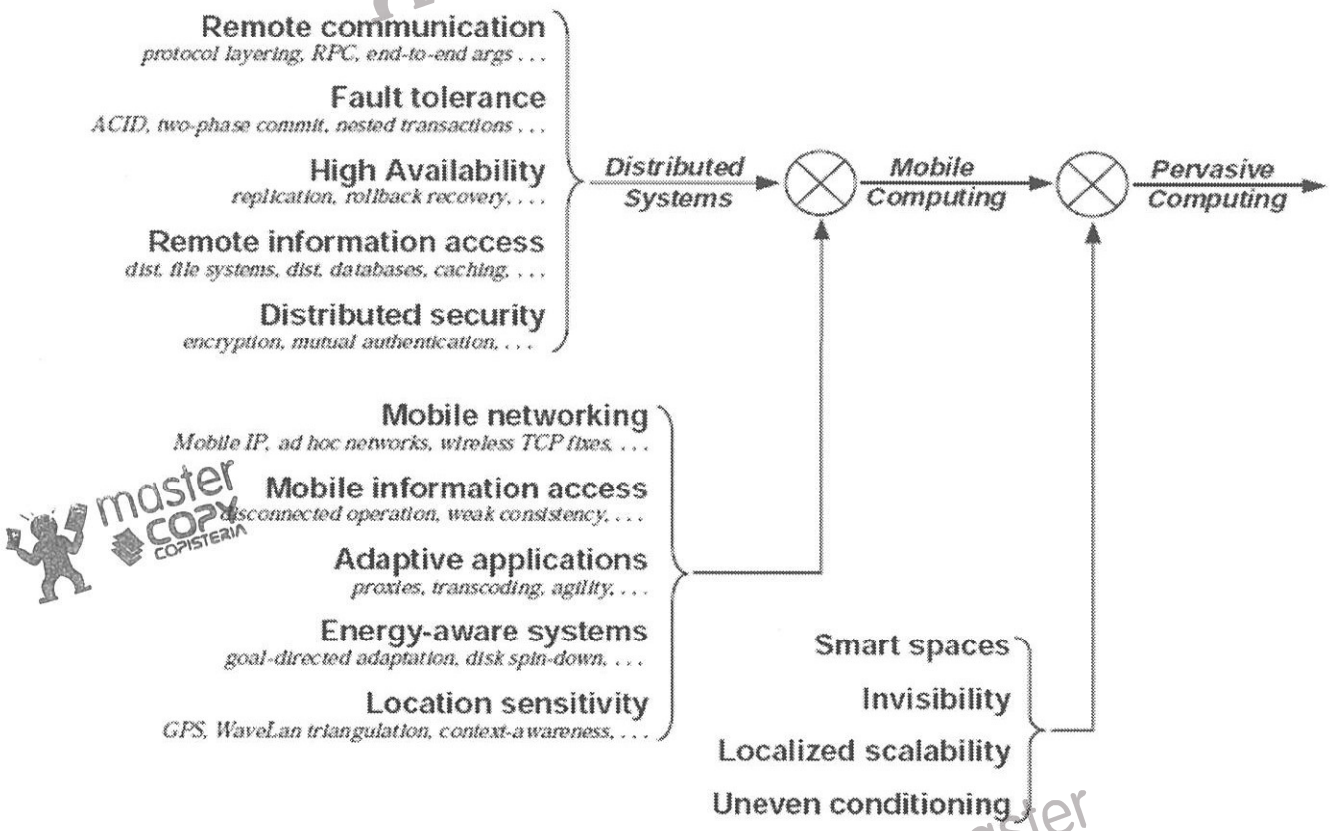
Now (1991) we are in the personal computing era, person and machine staring uneasily at each other across the desktop.

Next comes ubiquitous computing, or the age of calm technology, when technology recedes into the background of our lives.

Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence.

The most profound technologies are those that disappear.

They weave themselves into the fabric of everyday life until they are indistinguishable from it.



We can have two kinds of **mobility**:

- Physical mobility: hosts and users can change their geographical location while retaining the ability to communicate and perform computation.
- Logical mobility: application components or data can relocate at runtime, in order to have better performances or reach data to be processed. Ex. web pages with JavaScript.

Physical mobility is a requirement, logical mobility is a design choice.

Mobile Computing is a generic term describing your ability to use technology 'untethered'.

Mobile computers are generally battery powered. These include laptops, tablets, smartphones and wearable sensors.

Mobile devices are connected wirelessly to and through the Internet or a private network through wireless LAN or wireless WAN technology.

Wireless connection ties the mobile device to centrally located information infrastructure and application software (aka the "Cloud").
They move from location to location, while maintaining a connection to the fixed network
The load of computation and connectivity procedures are mainly carried out on the fixed network, especially with the cloud.
Services are provided by the core network to the mobile clients.

The goal of **pervasive computing**, which combines wireless computing, voice recognition, Internet capability and artificial intelligence, is to create an environment where the connectivity of devices should be unobtrusive and always available and the creation of environments saturated with computing and communication capability, yet gracefully integrated with human users.
Computing devices become progressively smaller and more powerful, a trend towards all man-made and some natural products having hardware and software.
Almost any device, from clothing, to tools, to appliances, to cars, to homes, to the human body, to your coffee mug, can be embedded with chips to connect the device to an infinite network of other devices.

A pervasive computing system that strives to be minimally intrusive has to be **context-aware.**
In other words, it must be cognizant of its user's state and surroundings, and must modify its behavior based on this information
A user's context can be quite rich, consisting of attributes such as physical location, physiological state (such as body temperature and heart rate), emotional state (such as angry, distraught, or calm), personal history, daily behavioral patterns, and so on.

Wearable sensors are smart devices, like smartwatches and fitness trackers, embed a wide range of sensors.
This massive amount of information has led to an increasing interest in the development of applications related to health and well-being.
A key challenge is represented by the reliable extraction of relevant patterns from collected signals.

Wireless Localization Techniques
Localization in Cyber-Physical-Systems (CPS) or in Wireless Sensor Networks (WSN) is the ability to determine the positions of components, sensors and events.
We need to be able to localize hardware components but also events.

A Cyber-Physical-Systems (CPS) is the new generation of networks and embedded systems:

- a computer system in which a mechanism is controlled or monitored by computer-based algorithms
- physical and software components are deeply intertwined, able to operate on different spatial and temporal scales
- interact with each other in ways that change with context

It is a distributed embedded system and here physical and software components are strongly tight together.
It tends to disappear, it is deeply embedded into the environment.

A Wireless Sensor Networks (WSN) is a networks of spatially dispersed and dedicated sensors that monitor and record the physical conditions of the environment and forward the collected data to a central location:

- built of "nodes" – from a few to hundreds or thousands, where each node is connected to other sensors. Each such node typically has several parts: a radiotransceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting
- WSNs can measure environmental conditions such as temperature, sound, pollution levels, humidity and wind

A WSN belongs to the domain of CPSs.
Every node is wirelessly connected. The energy is a critical problem here.

Localize means producing coordinates able to position the system and usable for location-aware applications or support network services.
Localization enables location-aware applications: products stored in a warehouse, medical personnel or equipment in a hospital, firemen in a building on fire, monuments/shops nearby.
Supports network services: track objects, report event origin, evaluate network coverage (enough node density) and assist with routing (geographical routing that do not use IP).

Localization systems consist of two main blocks:

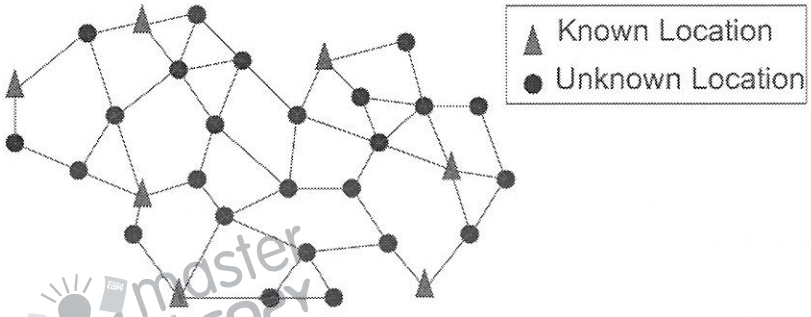
- the set of deployed nodes, into the environment
- the localization algorithm

Deployed nodes may have different states:

- Unknown
  Unknown nodes, referred to as **target** nodes, are those that do not have any information about their geographic locations.
  Over the time, unknown nodes may change their states to settled if they succeed to determine or estimate their locations.
- Beacon
  Beacon nodes, also referred to as landmarks or **anchors**, are those that already know their locations through a manual placement (e.g. deploy WSN with manually placement of each node in the network) or through GPS reading.
  With them everything is simper, the anchors are able to broadcast the position to let other nodes about it.
- Settled
  Thanks to the algorithm they determined or estimated their location.

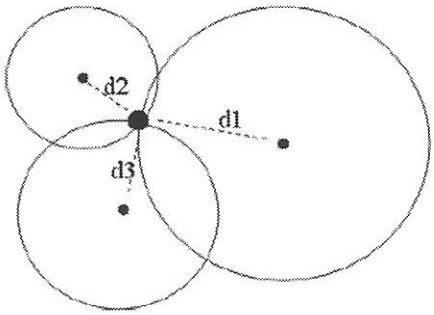
At the startup of the localization algorithm, nodes can either be in state beacon or unknown.
Both beacon and settled nodes are very useful for unknown nodes in order to estimate their locations as they could be considered as references.
Once an unknwon node becomes settled it can start helping the beacons in order for other unknown nodes to estimate their location, reaching a cooperative scheme where settled node behave like anchors.
If we use the distance between the unknown node and a settled node we talk about range-based techniques.

Anchor-based methods
The following is an example of network for anchor-based method.

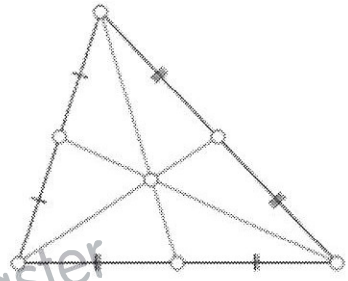


The density (unit/m^2) is important for location algorithms, higher will it be and more accurate will be the localization.
Anchor based-methods use geometric relations and usually evaluate the distance between targets and anchors by:

- Trilateration (range-based technique).
  In a first phase, unknown nodes must estimate their distance from an anchor and after an unknown collects a list of these distances, will be able to compute locally its position, which will be given by the intersection of three circles in a bidimensional plane, while four are needed with three dimensions



- Centroid (Range-free technique)
  They do not need to estimate distance from an anchor node. If a node is able to know the position of at least three nodes, it can estimate its position with the triangle using the three nodes as vertices.



The first one is more accurate, the second will have an error, depending on the dimensions of the triangle.
With a low density of anchors, we will have big triangles and so less accurate estimation of the position.

Localization algorithms aim at finding the location/position of unknown nodes
They describe the ways to determine the location depend on the objective of the cyber-physical application and the underlying technologies
Global Positioning System (GPS) is the intuitive and best solution to determine locations accurately.
However, we cannot use it always:
– not always the most effective solution for CPS, due to cost and energy constraints
– do not work indoor or when satellites are shielded

GPS-free techniques

Alternative techniques exploit (i) the sensing and (ii) the wireless communication capabilities of CPS components, estimating the position of nodes.

For example:

- use the Received Signal Strength (RSS), or propagation delay to infer the distances/angles to some reference nodes and then estimate the location through simple geometric computations (e.g. lateration/triangulation techniques).
  As the distance between transmitter and receiver increases, there is a inverse proportional law that allow to compute the distance.
  It will also depend on the environment, strong drawback.
  An advantage is that it is easy to get this parameter.
- estimate distances by exploiting the difference between heterogeneous waves' propagation properties (e.g., the reception time difference between acoustic and radio waves), if we can measure the time needed and know the propagation speed.
- range-free localization determines unknown node position based on proximity/ connectivity information. We though have less accuracy.

There are four different system **topologies** for localization systems, they determine where and how the location of a given node is calculated.

1. Remote positioning: anchor nodes collect transmitted radio signals from the mobile node and forward them to the base station. The latter computes the estimated position of the mobile node based on the measured signals forwarded by the anchors.
   Location of a node is computed at a central base station. Anchor nodes collect radio signal transmitted by unknown nodes and forward them to a base station where computation takes place.
   Unknown nodes must only transmit these kinds of information to anchors and anchors must send this information to the central base station.
   We have that the biggest energy consumption is mainly due to communication and not computation.
2. Self-positioning: the location of a mobile node is computed by itself based on the measured signals that it receives from anchor nodes. Unknown nodes after having received a number for messages from anchors compute locally their position.
   E.g. GPS
3. Indirect remote positioning: like in the self-positioning case, the mobile node computes its locations and sends it to a base station through a wireless back channel.
   It uses the same scheme with the addition of the forwarding to the base station.
4. Indirect self-positioning: like in the remote positioning, the location of the mobile node is computed at the base station, then the base station forwards the estimated position to the mobile node, through a wireless back channel.

Coordinate System

We have two dimensions of coordinate.

The first one regards:

- Absolute: locations are expressed as unique coordinate values referring to special nodes that know their positions, which are mainly the anchor nodes (4 anchors are needed in a 3D coordinate system). They are numbers that refer to a global referring positioning system.