Unit – 5
Web of Things
and
Cloud of Things

Web of Things

- Term used to describe approaches, software architectural styles and programming patterns that allow real-world objects to be part of the WWW
- Provides an Application Layer that simplifies the creation of Internet of Things applications
- Rather than re-inventing completely new standards, Web of Things reuses existing and well-known Web standards

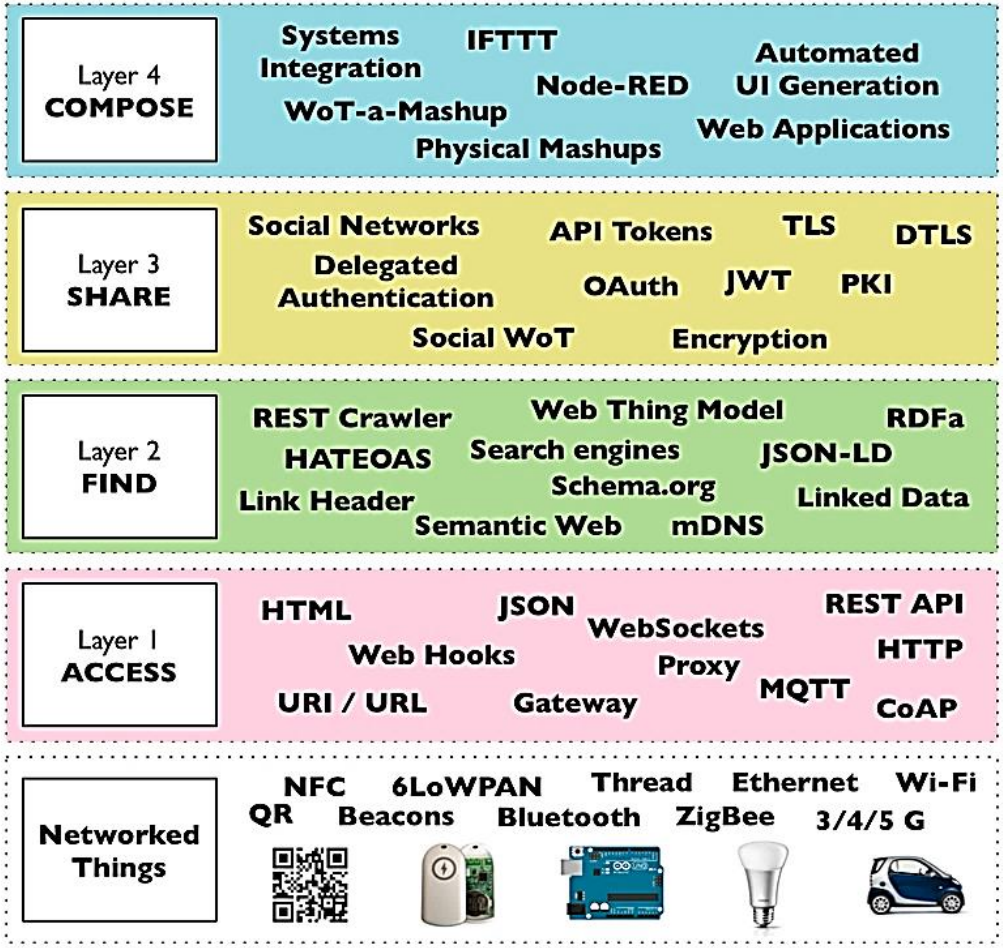
Web of Things Architecture

Integrate the services and data offered by things into higher level Web tools

Ensures that data generated by things can be shared in an efficient and secure manner

Provide a way to find and locate things on the Web

Deals with the access of things to the Internet and ensure they expose their services via Web APIs



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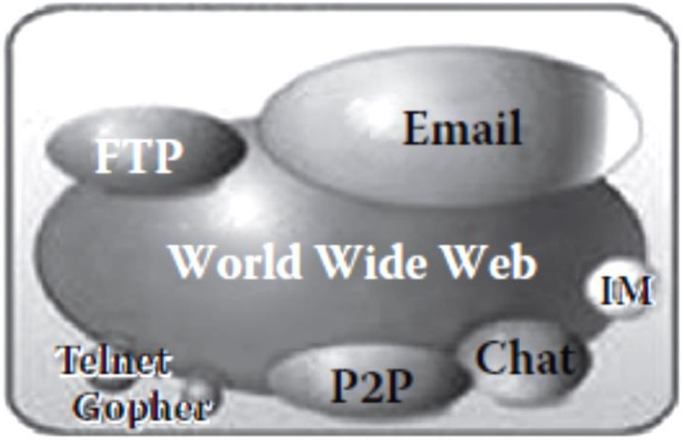
Web of Things Vs. Internet of Things

- Firstly distinguish the difference between the Internet and the World Wide Web
- Internet is the term used to identify massive inter-connection of computer networks around world
- Physical connection of the paths between two or more computers
- World Wide Web is the general name for accessing the Internet via HTTP
- It is just one of the connection protocols that is available in the Internet

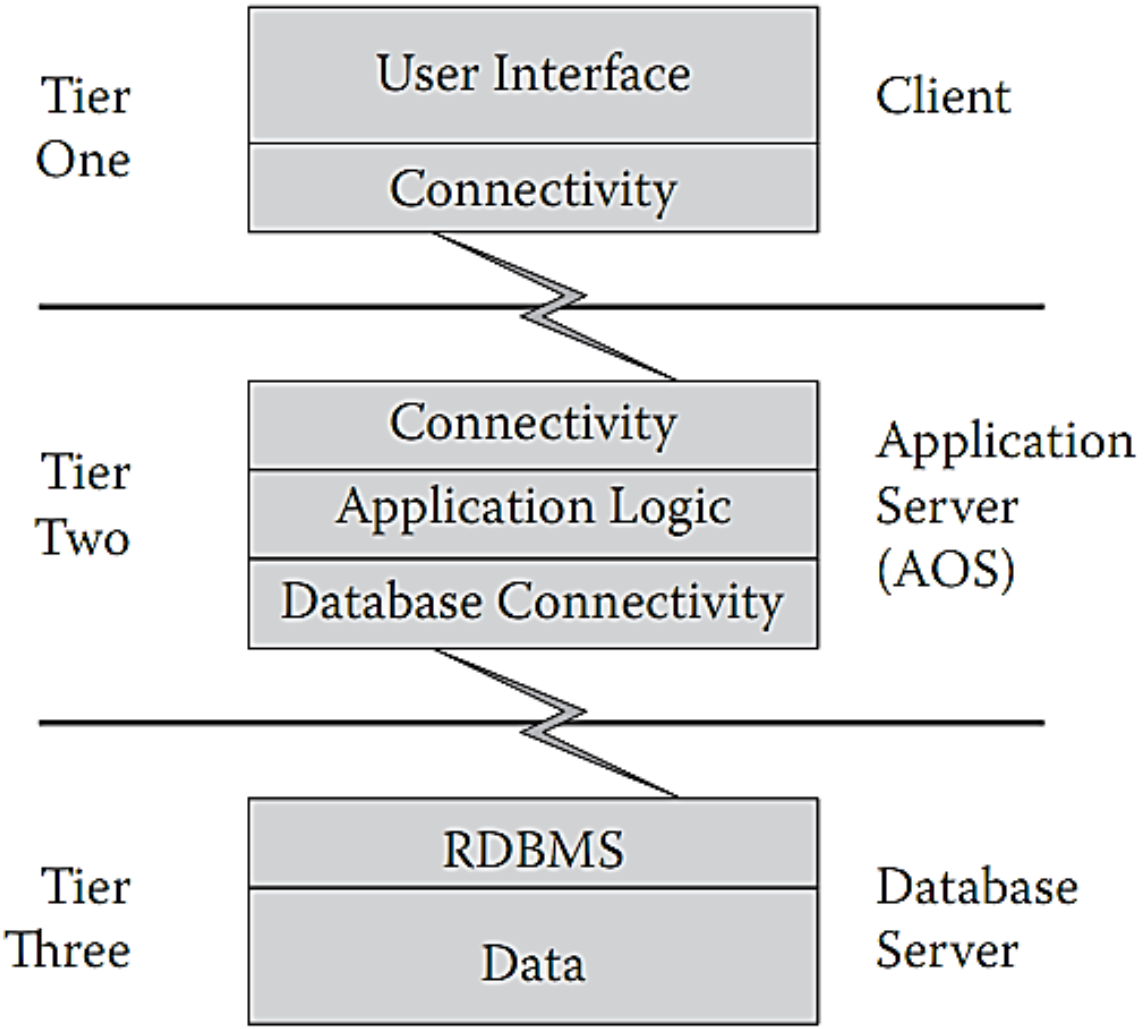
Web of Things Vs. Internet of Things

- Internet is the large container and the web is a part within the container
- To be technically precise, if Internet is restaurant, the web is the most popular dish on the menu
- However, it's *the dishes* that make the Internet popular, useful to everyone and powerful



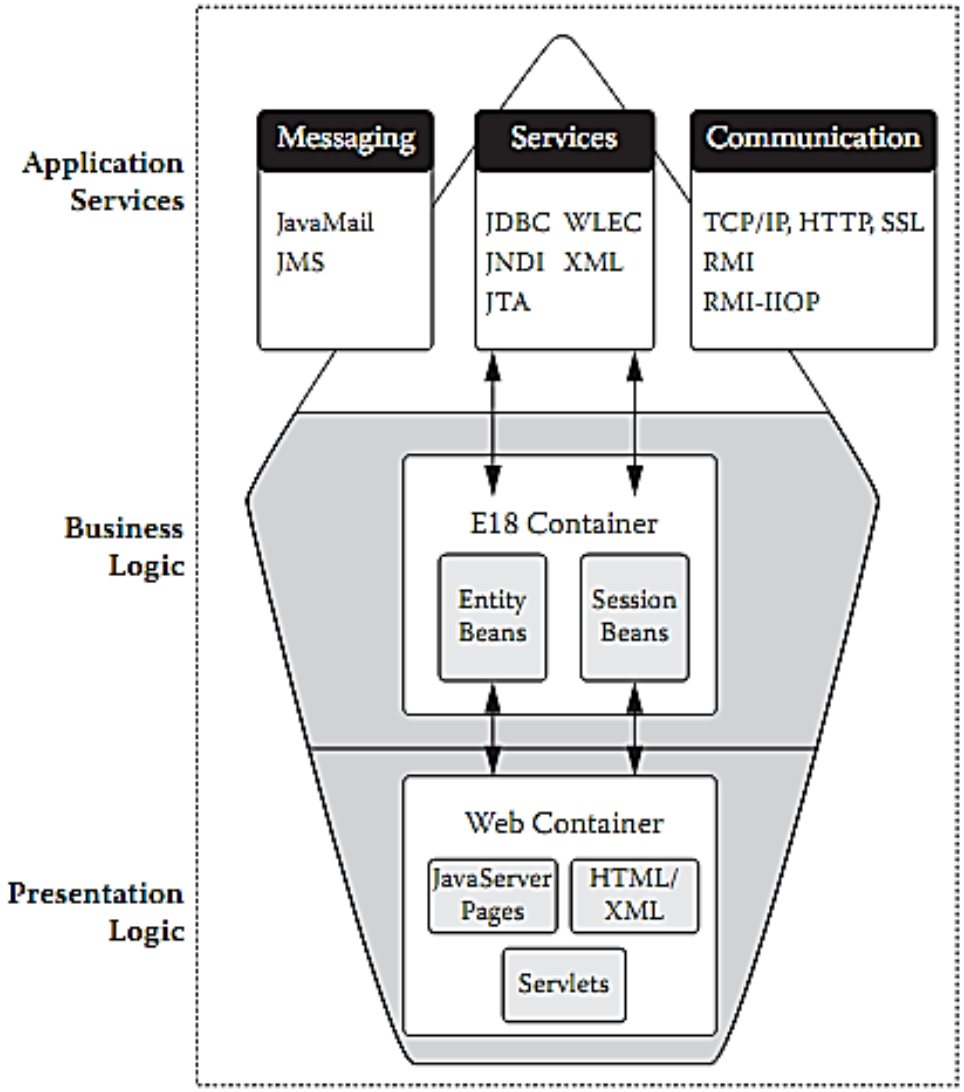
Two Pillars of the Web

Three- tiered Architecture

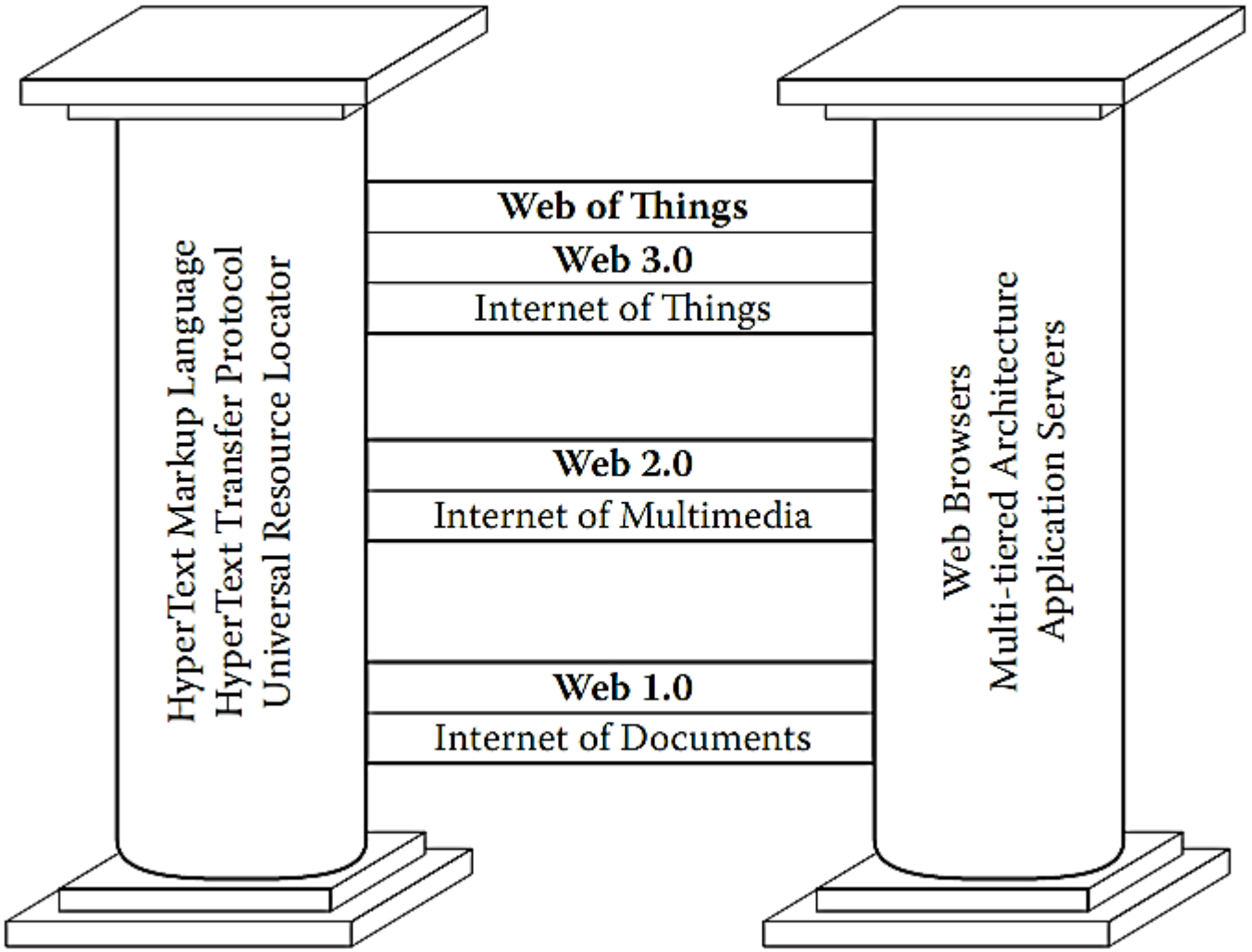


Two Pillars of the Web

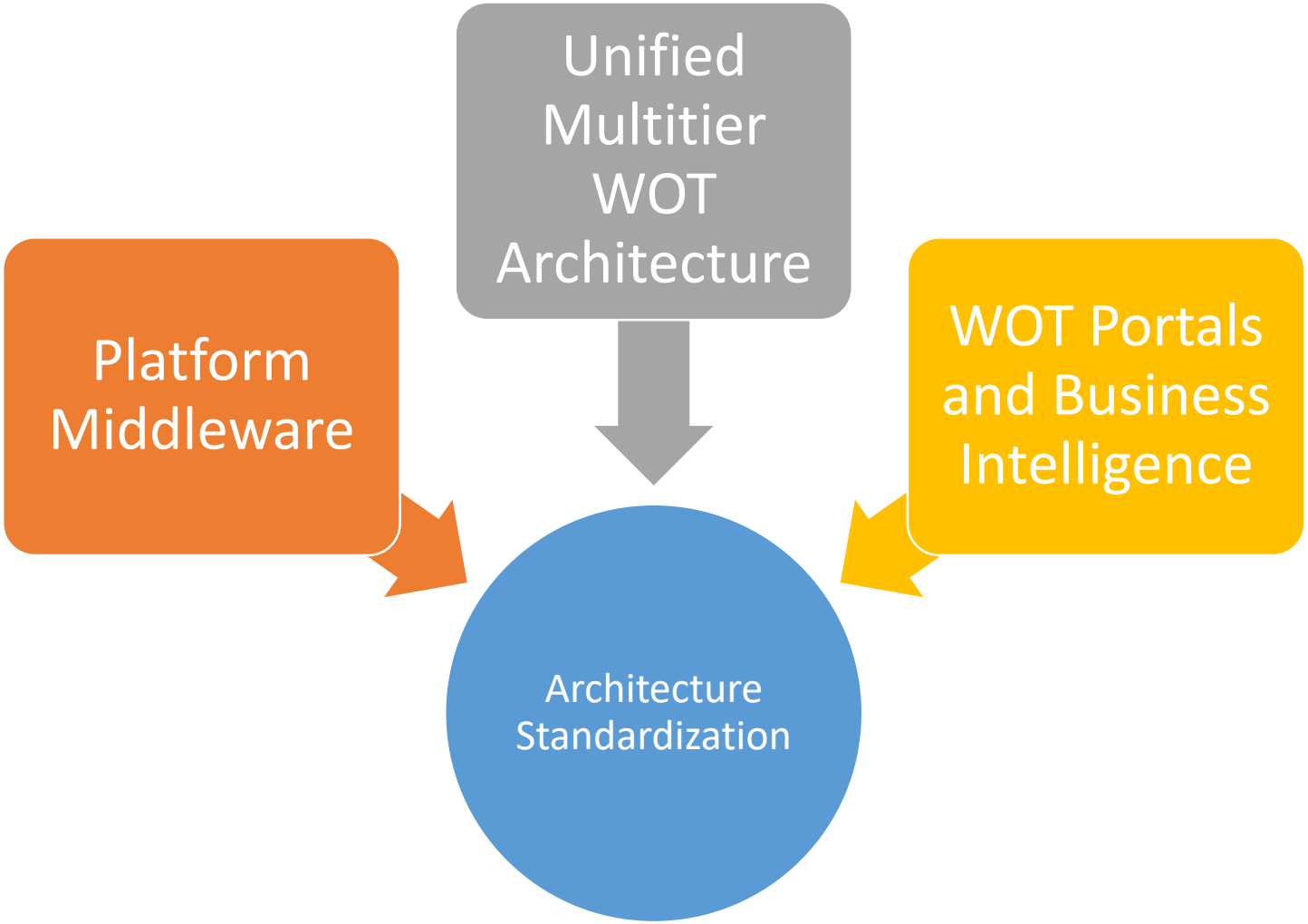
Java-Based Application Servers



Two Pillars of the Web



Architecture Standardization for WOT



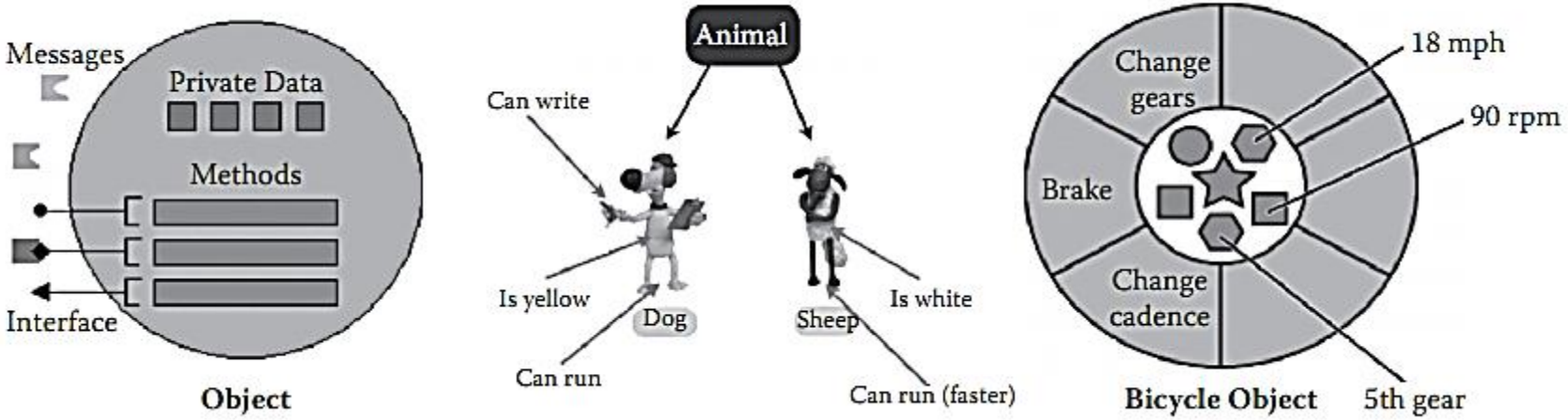
Platform Middleware for WOT

- Communication middleware and platform middleware are closely related with each other
- Platform Middleware or Application Frameworks or Three- Tiered Application Server
- Goal is to bring the IOT applications to the World Wide Web
- According to WOT/ IOT vision, everyday objects will be connected with each other and with Internet
- These will form a distributed network with sensing capabilities

Platform Middleware for WOT

- Observation is that many software architectures & technologies are already using term *object* such as,
  - Object- Oriented Design
  - Object- Oriented Software Engineering And Programming
  - CORBA (Common Object Request Broker Architecture)
  - DOM (Document Object Model)
  - POJO (Plain Old Java Object)
  - COM (Component Object Model) & DCOM (Distributed COM)
  - OPC (Object Linking and Embedding for Process Control)
  - OID (Object Identification)
  - SOAP (Simple Object Access Protocol)
  - JSON (JavaScript Object Notation) and so on

Platform Middleware for WOT



Unified Multitier WOT Architecture

- SOA/EAI versus SODA/MAI
  - WOT/ IOT applications should inherit and enhance the existing data formats and protocols
  - SOAP (simple object access protocol) is a protocol framework specification for exchanging structured information in the implementation of web services
  - It relies on XML for its message format
  - Usually hypertext transfer protocol (HTTP), simple mail transfer protocol (SMTP), Java messaging services (JMS)
  - SOA is a set of principles and methodologies for designing and developing software in the form of interoperable services, usually over the Internet

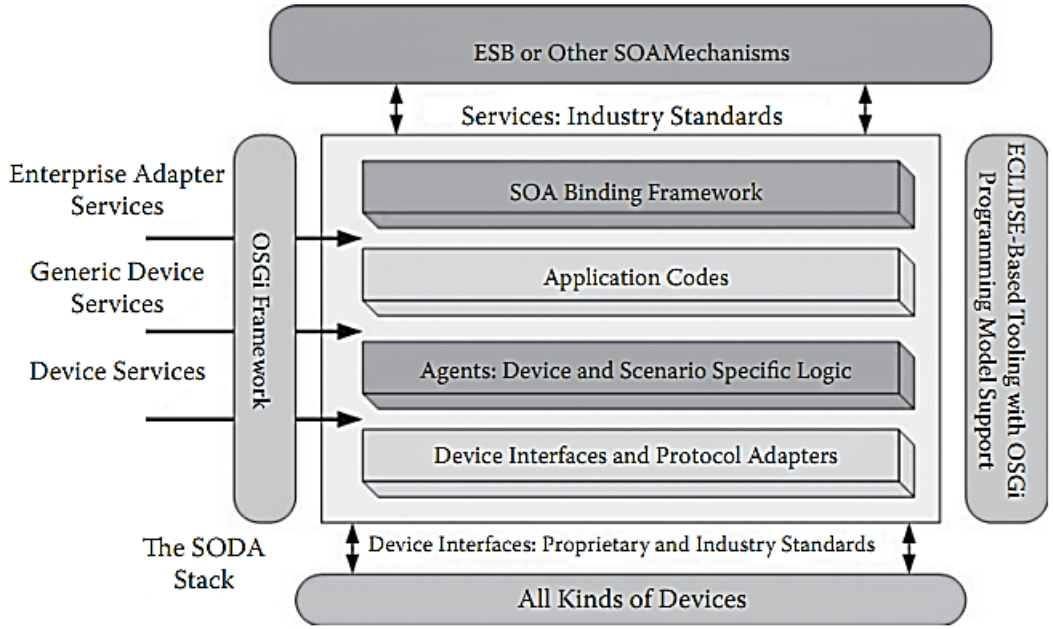
Unified Multitier WOT Architecture

- SOA requires metadata (unified WoT architecture also needs metadata)
- Web services description language typically describes the services, while the SOAP protocol describes the communication protocols
- Combination of existing SOA and EAI (Enterprise Application Integration) technologies is a good foundation for WOT/ IOT applications
- Service- Oriented Device Architecture (SODA) is proposed to enable device connection to an SOA

Unified Multitier WOT Architecture

- Core of SODA standard is DDL (device description language) based on XML encodings
- DDL classifies devices into three categories: sensors, actuators, and complex devices

SODA Architecture



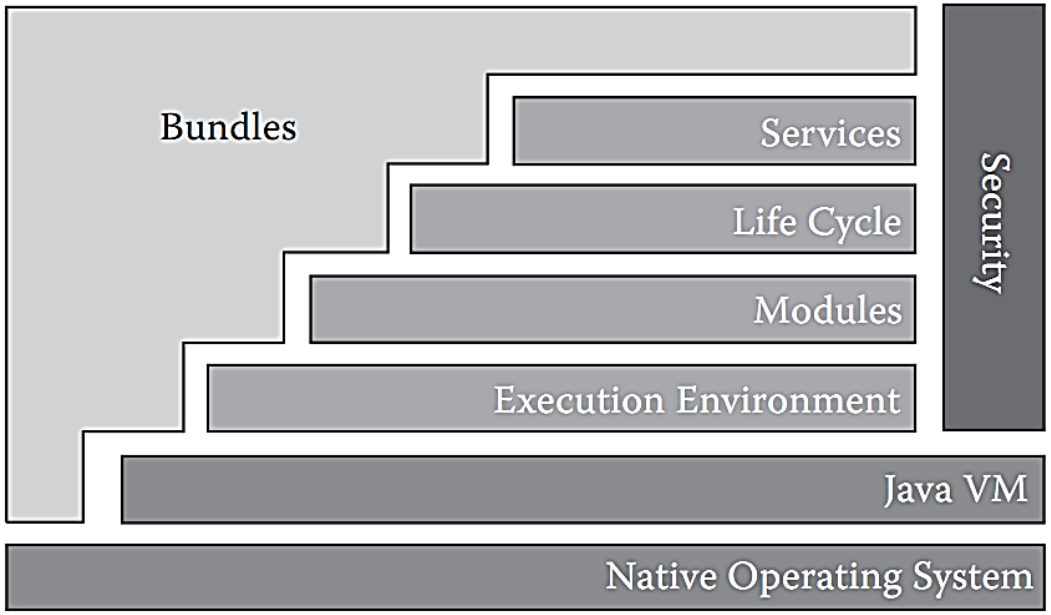
Unified Multitier WOT Architecture

- Example of Device Description Language of SODA

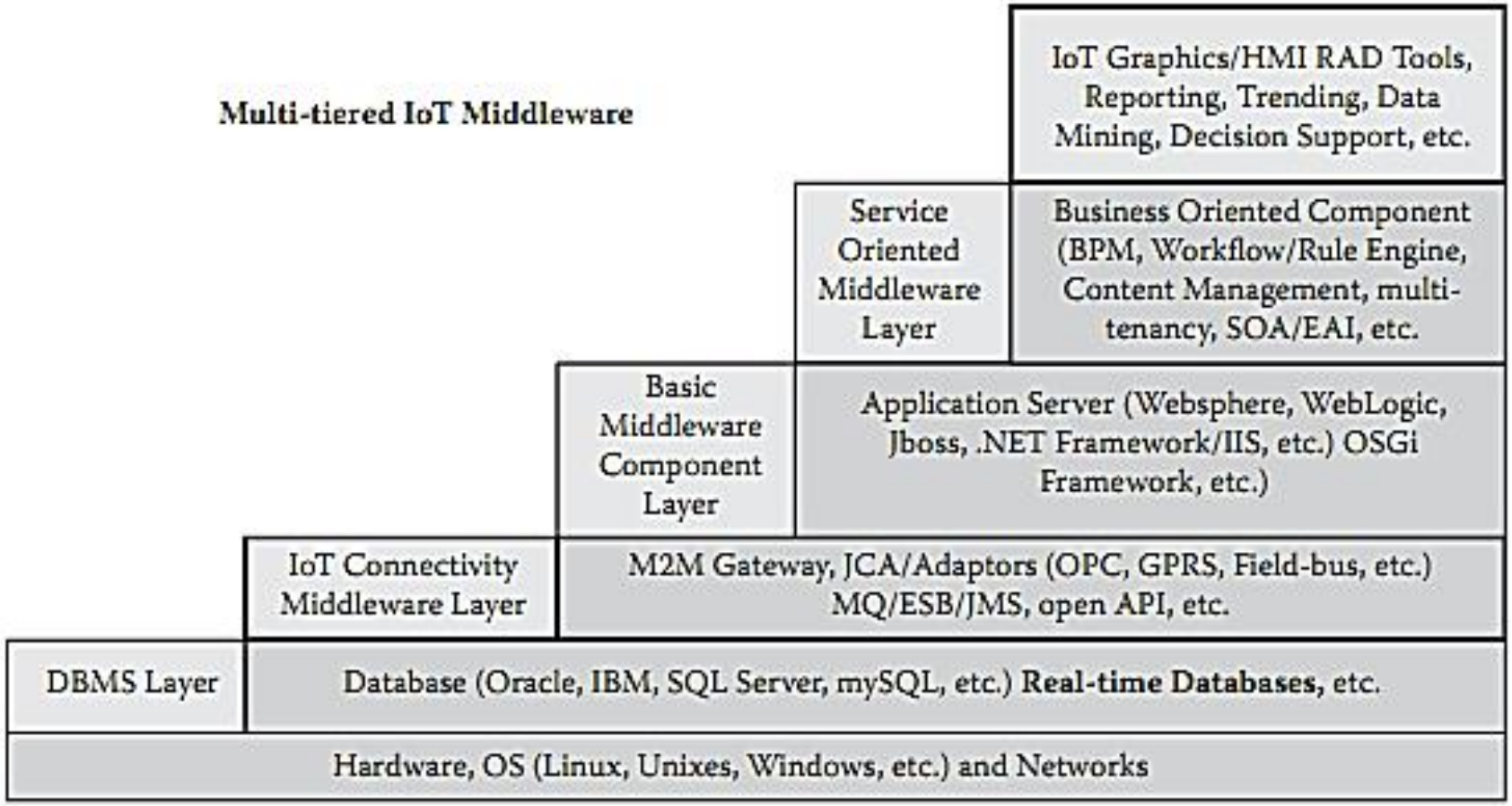
```
<Sensor>
<Description>…</Description>
<Interface>
<Signal id = "ADC1">…</Signal>
<Reading id = "Temp 1">
<Type>Physical</Type>
<Measurement>Temperature</Measurement>
<Unit>Centigrade</Unit>
<Computation>
<Type>Formula</Type>
<Expression> Temp 1 = (((ADC1/1023 * 3.3)-0.5)*
(1000/10)</Expression>
</Computation>
</Reading>
</Interface>
</Sensor>
```

Unified Multitier WOT Architecture

- OSGi: The Universal Middleware
  - Open Services Gateway initiative
  - Module system and service platform for the Java programming language that implements complete and dynamic component model



Unified Multitier WOT Architecture



WOT Portals and Business Intelligence

- Web portal - website that functions as a point of access to information in the World Wide Web
- Portal presents information from diverse sources in a unified way
- Examples of public web portals include Yahoo, AOL, Excite, MSN
- Apart from standard search engine feature, web portals offer other services such as e- mail, news, stock prices, information, databases and entertainment

WOT Portals and Business Intelligence

- Categorizations of portals:
  - Horizontal Portals - cover many areas
  - Vertical Portals - focused on one functional area
- WOT portals are vertical portals
- When huge amount of data are collected in a IOT system, data mining can be conducted to acquire business intelligence (BI)
- Data mining deals with finding patterns in data that are by user definition, interesting and valid
- Interdisciplinary area -databases, machine learning, pattern recognition, statistics, visualization, etc.

WOT Portals and Business Intelligence

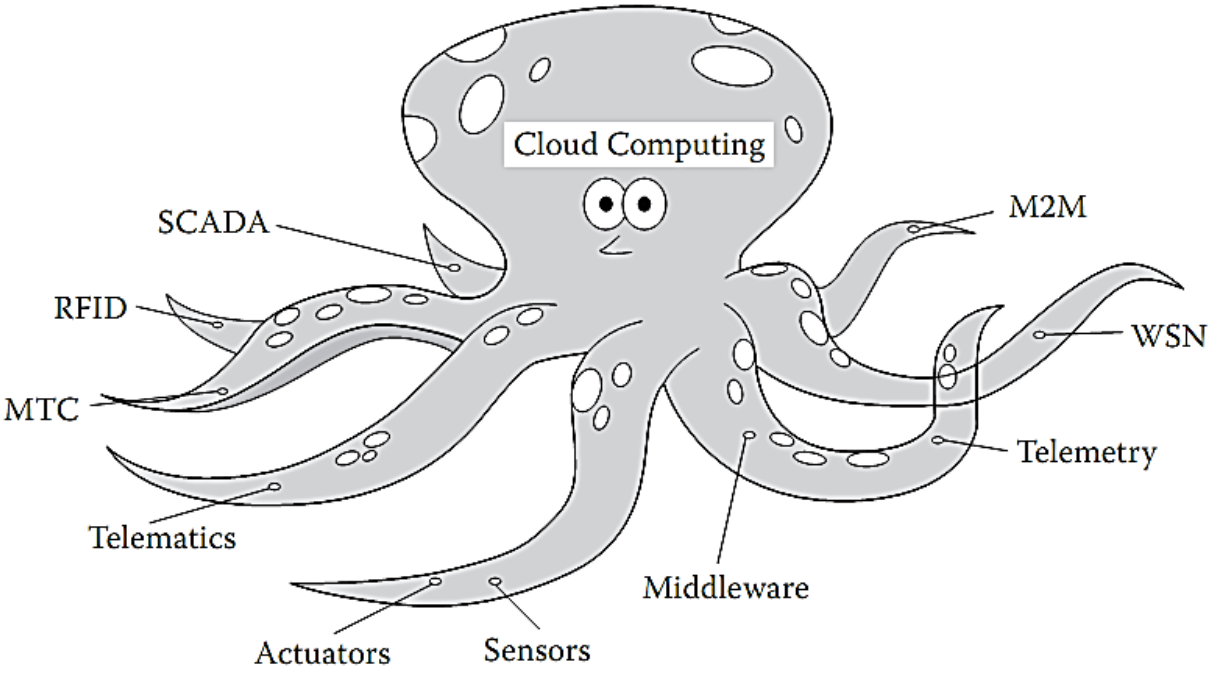
- BI technologies provide historical, current, and predictive views of business operations
- Common functions of BI technologies are
  - extract, transform, and load
  - reporting, online analytical processing, analytics
  - data mining, process mining, complex event processing
  - business performance management, benchmarking, text mining, predictive analytics, and so on

Cloud of Things

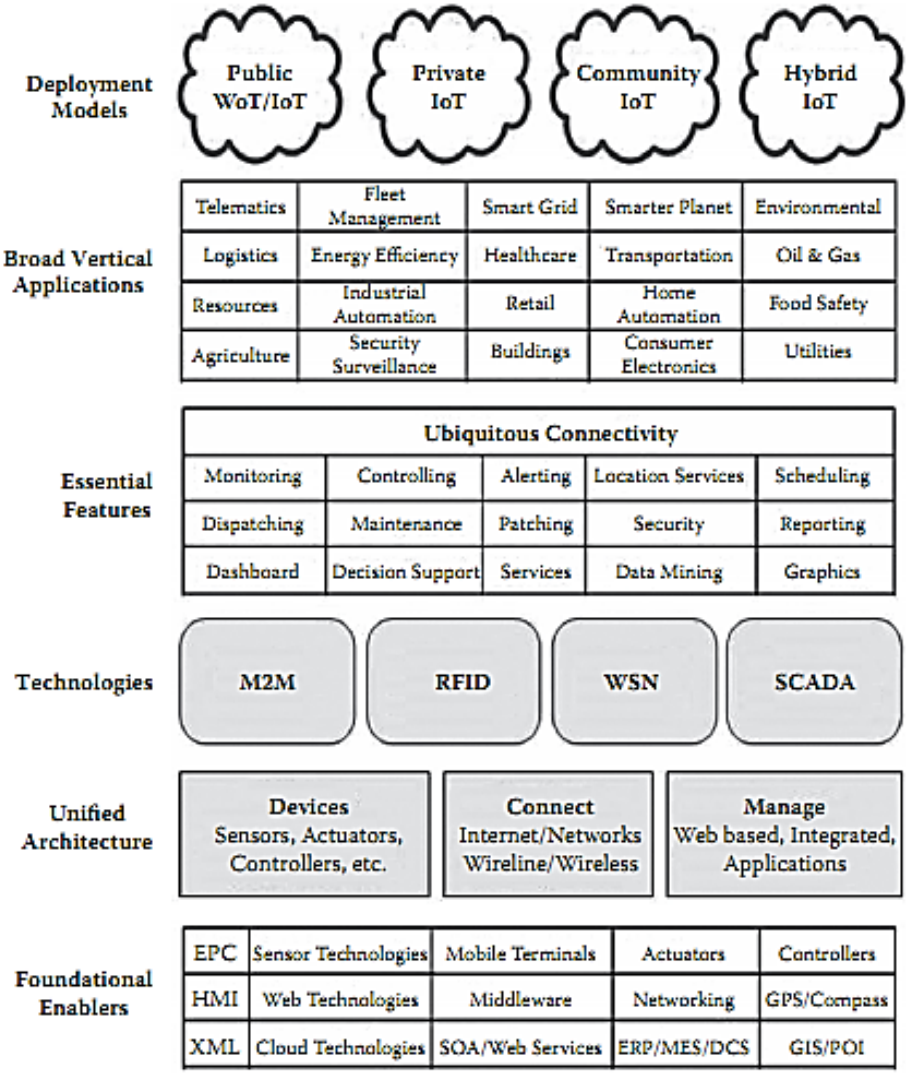
- Internet of Things (IOT) and cloud computing
- Internet of Things is not as popular as cloud computing
- Because IOT is referred to by different terms such as machine- to- machine (M2M), connected world, smarter planet, smart grid, etc.
- But machine to machine is a more popular term than cloud computing
- Both IOT and cloud computing can be categorized as distributed computing

Cloud of Things

- Have many things in common or closely related:
  - Both are a type of distributed computing that relies heavily on communication networks
  - Cloud computing is an enabling technology of the IOT



Cloud of Things Architecture



Mobile Cloud Computing

- Potential of cloud computing doesn't stop at turning the personal computer into a thin client
- Mobile application market is about to change radically due to the emergence of widgets, most compelling of mobile cloud applications
- Much has been made of mobile application phenomenon popularized by Apple's iconic iPhone
- Smartphones are becoming thin clients of cloud services
- Apple's iCloud services, announced in June 2011 that run on Amazon Web Service and Microsoft Azure IaaS, symbolize the start of Cloud Phones

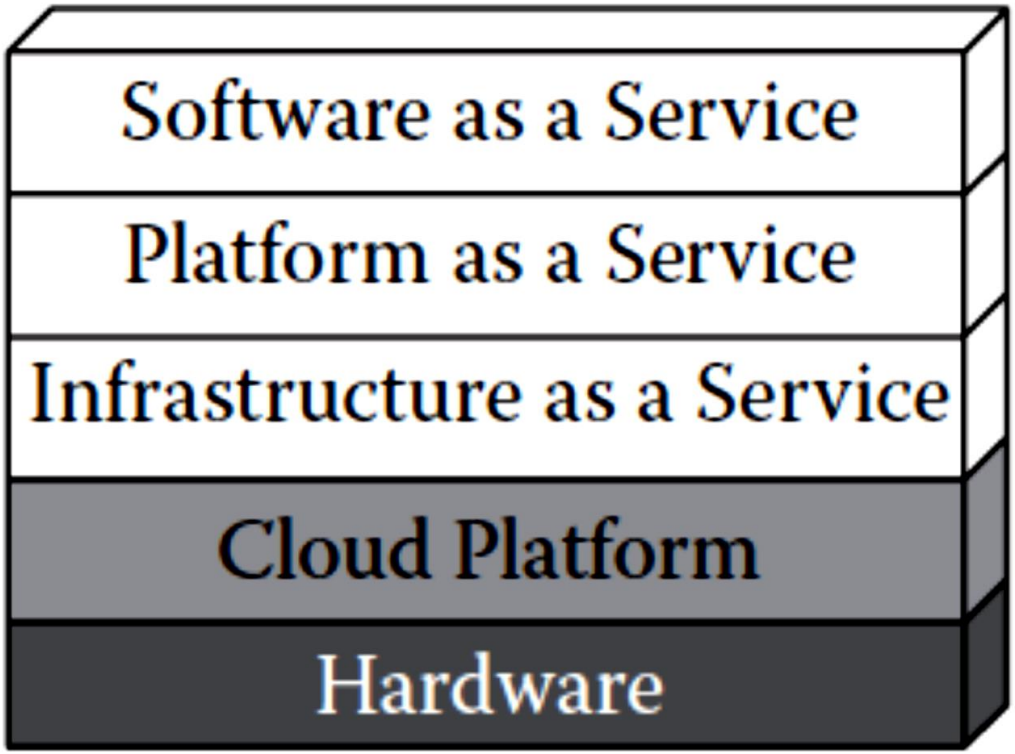
Mobile Cloud Computing

- Currently, most widgets downloaded from app stores or Android markets are not cloud applications by definition
- Because they do not receive services from the cloud during runtime
- Large number of them are cloud applications such as LBS applications, data synchronization, weather forecast, bank client, etc., applications
- In fact, a large percentage of Android and iPhone widgets are already cloud services based
- This is real mobile cloud computing (mCC)

Cloud Computing

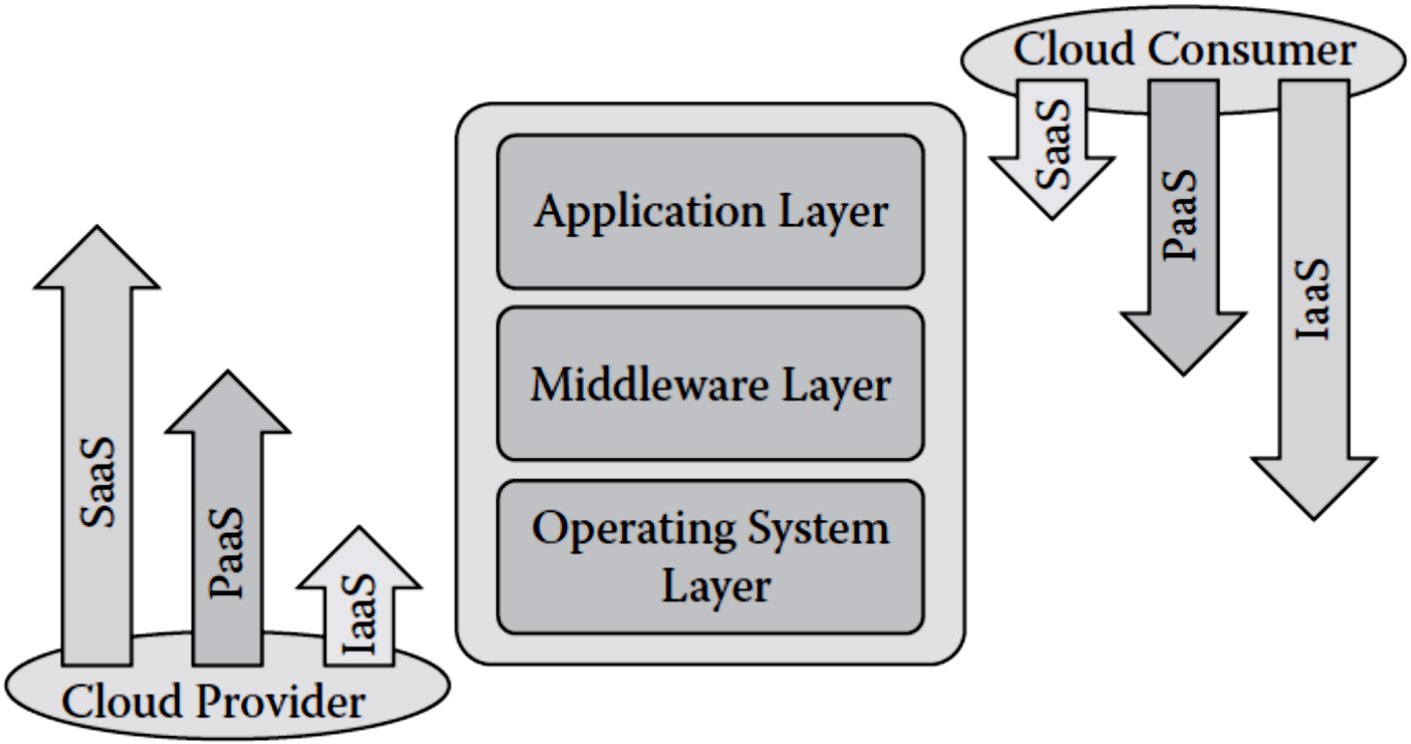
- It starts with the premise that the data services and architecture should be on servers
- They should be in a ‘cloud’ somewhere
- And that if you have the right kind of browser or the right kind of access, it doesn’t matter
  - whether you have a PC or a Mac or
  - A mobile phone or a BlackBerry or what have you—or
  - New devices still to be developed—you can get access to the cloud
- Term *cloud* was used as a metaphor for the Internet

Cloud Hierarchy



Cloud Middleware

- Like IOT, cloud computing system is also a multi tiered architecture built on a middleware stack



Cloud Middleware

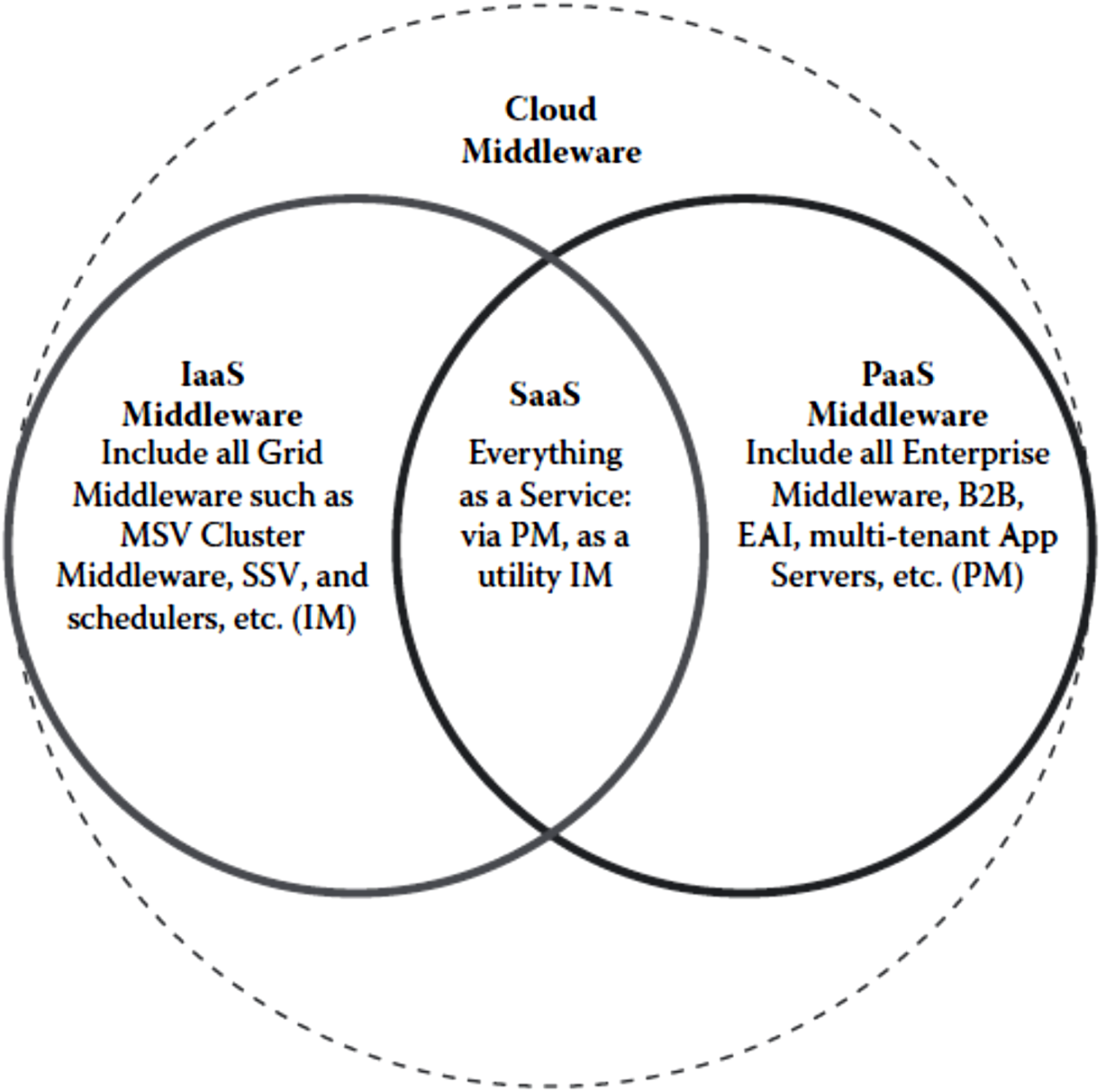
- As an example, VAMOS [242], built by IBM, is a novel middleware architecture that runs its middleware modules at the hypervisor level
- Reduces I/O virtualization overhead by cutting down on the overall number of guest/hypervisor switches for I/O intensive workloads
- Applying VAMOS to a database application improved its performance by up to 32 percent
- Here, the middleware concept is extended to include software that does IPC not necessary over a network

Cloud Middleware

- At the cluster computing or grid computing level, many types of work are done by middleware
- Parallel computing environments such as PVM and MPI are middleware by definition
- Hadoop system and the job scheduler such as Condor, LoadLeveler, and others are all middleware
- A number of grid middleware initiatives have been formed
- Some of those middleware are aggregately referred to as grid middleware

Cloud Middleware

- Various grid middleware are
  - Low-level middleware
  - MPI, Open MPI
  - PVM (parallel virtual machine)
  - POE (parallel operating environment, IBM)
  - Middleware for file systems and resources
  - MPI-IP
  - PVFS/GPFS (parallel virtual file system/general parallel file system IBM)
  - Sector-Sphere
  - Condor/PBS/LoadLeveler (IBM)
  - High-level middleware
  - Beowolf
  - Globus Toolkit
  - Gridbus
  - Legion
  - Unicore
  - OSCAR/CAOS/Rocks
  - OpenMosix/NSA/Perceus


Cloud
Middleware
IaaS
Middleware
Include all Grid Middleware such as MSV Cluster Middleware, SSV, and schedulers, etc. (IM)
SaaS
Everything as a Service: via PM, as a utility IM
PaaS
Middleware
Include all Enterprise Middleware, B2B, EAI, multi-tenant App Servers, etc. (PM)

Cloud Standards

- Cloud model is composed of the following:
  - Three service models: IaaS, PaaS, and SaaS
  - Four deployment models: private cloud, public cloud, community cloud, and hybrid cloud
  - Five essential characteristics: on-demand self-service, broad network access, resource pooling, rapid elasticity, and measured service