MODULE - I

M2M to IoT
Introduction: The Vision-Introduction, From M2M to IoT, M2M towards IoT-the global context, A use case example, Differing Characteristics

1.1Introduction: The Vision-Introduction

Our world is on the verge of an amazing transformation; one that will affect every person, town, company, and thing that forms the basis of our society and economy. In the same way that the Internet redefined how we communicate, work, and play, a new revolution is unfurling that will again challenge us to meet new business demands and embrace the opportunities of technical evolution. Old and new industries, cities, communities, and individuals alike will need to adapt, evolve, and help create the new patterns of engagement that our world desperately needs. In response to these issues, we are moving towards a new era of intelligence-one driven by rapidly growing technical capabilities.

M2M and the IoT are two of the technologies that form the basis of the new world that we will come to inhabit. Anything in the physical realm that is of interest to observe and control by people, businesses, or organizations will be connected and will offer services via the Internet. The physical entities can be of any nature, such as buildings, farmland, and natural resources like air, and even such personal real-world concepts my favorite hiking route through the forest or my route to work.

1.2From M2M to IoT

Machine-to-Machine towards an emerging paradigm known as the *Internet of Things.* Often these terms are interchangeably.

1.2.1 A Brief Background

- Both M2M and IoT are results of the technological progress over the last decades, including not just the decreasing costs of semiconductor components, but also the spectacular uptake of the Internet Protocol (IP) and the broad adoption of the Internet.
- The application opportunities for such solution are limited only by our imaginations; however, the role that M2M and IoT will have in industry and broader society is just starting to emerge for a series of interacting and interlinked reasons.
- The Internet has undoubtedly had a profound impact on society and industries.
- Starting off as ARPANET connecting remote computers together
    - o the introduction of the TCP/IP protocol suite,
    - o email and the World Wide Web (WWW)
- created a tremendous growth of usage and traffic.
- In conjunction with innovations that dramatically reduced the cost of semiconductor technologies and the subsequent extension of the Internet at a reasonable cost via mobile networks, billions of people and businesses are now connected to the Internet.

- At the same time that the Internet has been evolving, another technology revolution has been unfolding-the use of sensors, electronic tags, and actuators to digitally identify, observe and control objects in the physical world.
- Rapidly decreasing costs of sensors and actuators have meant that where such components previously cost several Euros each, they are now a few cents. In addition, these devices, through increases in the computational capacity of the associated chipsets, are now able to communicate via fixed and mobile networks. As a result, they are able to communicate information about the physical world in near real-time across networks with high bandwidth at low relative cost.
- M2M solutions was for quite some time, Now entering a period of time where both M2M and IoT solutions will increase dramatically.
- The reasons for this are three-fold:
  1. An increased need for understanding the physical environment in its various forms, from industrial installations through to public spaces and consumer demands. These requirements are often driven by efficiency improvements, sustainability objectives, or improved health and safety (Singh 2012).
  2. The improvement of technology and improved networking capabilities.
  3. Reduced costs of components and the ability to more cheaply collect and analyze the data they produce.

- What makes the M2M and IoT markets take off today, enabling technologies at the right cost.

1.2.2 M2M Communication

- M2M refers to those solutions that allow communication between devices of the same type and a specific application, all via wired or wireless communication networks.
- M2M solutions allow end-users to capture data about events from assets, such as temperature or inventory levels.
- M2M is deployed to achieve
  - productivity gains,
  - reduce costs, and
  - increase safety or security.
- M2M has been applied in many different scenarios, including the remote monitoring and control of enterprise assets, or to provide connectivity of remote machine type devices.
- Remote monitoring and control has generally provided the incentive for industrial applications, whereas connectivity has been the focus in other enterprise scenarios such as connected vending machines or point-of-sales terminals for online credit card transactions.
- M2M solutions, however, do not generally allow for the broad sharing of data or connection of the devices in question directly to the Internet.

1.2.2.1 A Typical M2M solution overview

- A typical M2M system solution consists of
  - M2M devices
  - communication networks that provide remote connectivity for the devices,
  - service enablement, application logic,
  - Integration of the M2M application into the business processes provided by an Information Technology (IT) illustrated in the below figure 1.1
- The M2M system solution is used to remotely monitor and control enterprise assets of various kinds, and to integrate those assets into the business processes of the enterprise in question. The asset can be of a wide range of types (e.g. vehicle, freight container, building, or smart electricity meter), all depending on the enterprise.

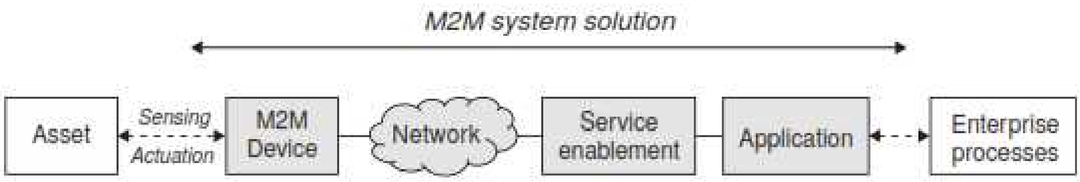

Figure 1.1 A Generic M2M system solution

- The system components of an M2M solution are as follows:
  - ***M2M Device***. This is the M2M device attached to the asset of interest and provides sensing and actuation capabilities. The M2M device is here generalized, as there are a number of different realizations of these devices, ranging from low-end sensor nodes to high-end complex devices with multimodal sensing capabilities.
  - ***Network***. The purpose of the network is to provide remote connectivity between the M2M device and the application-side servers. Many different network types can be used and include both Wide Area Networks (WANs) and Local Area Networks (LANs). Examples of WANs are public cellular mobile networks, fixed private networks, or even satellite links.
  - ***M2M Service Enablement***. Within the generalized system solution outlined above, the concept of a separate service enablement component is also introduced. This component provides generic functionality that is common across a number of different applications. Its primary purpose is to reduce cost for implementation and ease of application development.
  - ***M2M Application***. The application component of the solution is a realization of the highly specific monitor and control process. The application is further integrated into the overall business process system of the enterprise. The process of remotely monitoring and controlling assets can be of many different types, for instance, remote car diagnostics or electricity meter data management.

1.2.2.2 Key Application areas

- Existing M2M solutions cover numerous industry sectors and application scenarios. Various predictions have been made by analyst firms that provide market information such as key applications, value chains, and market actors, as well as market sizes (including forecasts).
- A selected summary of main cellular M2M application markets is provided in Figure 1.2, and the figures are estimates of deployed numbers of corresponding M2M devices in the years 2012 and 2016, respectively.
- The largest segment is currently Telematics for cars and vehicles. Typical applications include navigation, remote vehicle diagnostics, pay-as-you-drive insurance schemes, road charging, and stolen vehicle recovery.

- **Telematics**: The technology of sending, receiving and storing information using telecommunication devices to control remote objects
- **Metering applications**: meanwhile, include primarily remote meter management and data collection for energy consumption in the electricity utility sector, but also for gas and water consumption.
- **Remote monitoring**: is more generalized monitoring of assets, and includes remote patient monitoring as one prime example.
- **Fleet management:** includes a number of different applications, like data logging, goods and vehicle positioning, and security of valuable or hazardous goods.
- **Security applications:** are mainly those related to home alarms and small business surveillance solutions. The final market segment is Automated Teller Machines (ATM) and Point of Sales (POS) terminals.

1.2.3 IoT

- The **Internet of Things** (**IoT**) is the network of physical devices embedded with electronics, software, sensors, actuators, and connectivity which enables these things to connect and exchange data.
- The IoT is a widely used term for a set of technologies, systems, and design principles associated with the emerging wave of Internet-connected things that are based on the physical environment. In many respects, it can initially look the same as M2M communication _ connecting sensors and other devices to Information and Communication Technology (ICT) systems via wired or wireless networks.
- In contrast to M2M, however, IoT also refers to the connection of such systems and sensors to the broader Internet, as well as the use of general Internet technologies.

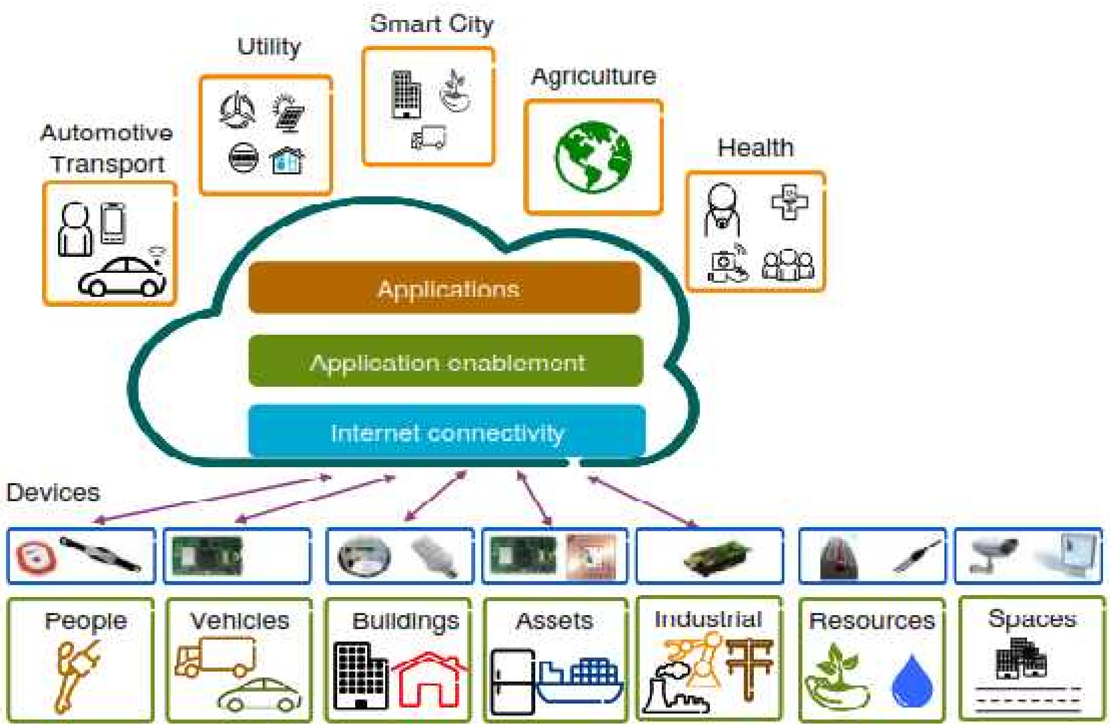

Figure 1.2 An IoT

- IoT is about the technology, the remote monitoring, and control, and also about where these technologies are applied. IoT can have a focus on the open innovative promises of the technologies at play, and also on advanced and complex processing inside very confined and close environments such as

Emerging IoT Applications

Urban Agriculture: By using IoT technologies, urban agriculture could be highly optimized. Sensors and actuators can monitor and control the plant environment and tailor the conditions according to the needs of the specific specimen. Water supply through a combination of rain collection and remote feeds can be combined on demand. A vision of urban agriculture is to be a self-sustaining system. Urban agriculture can be a mix of highly industrialized deployments with vertical greenhouses, and collective efforts by individuals in apartments by the use of more do-it-yourself style equipment.

Robots: The mining industry is undergoing a change for the future. Production rates must be increased, cost per produced unit decreased, and the lifetime of mines and sites must be prolonged. In addition, human workforce safety must be higher, with fewer or no accidents, and environmental impact must be decreased by reducing energy consumption and carbon emissions. The mining industry answer to this is to turn each mine into a fully automated and controlled operation. The process chain of the mine involving blasting, crushing, grinding, and ore processing will be highly automated and interconnected. The heavy machinery used will be remotely controlled and monitored, mine sites will be connected, and shafts monitored in terms of air and gases.

Food Safety: The main objective with is to ensure that the U.S. food supply is safe. These objectives will have an impact across the entire food supply chain, from the farm to the table, and require a number of actors to integrate various parts of their businesses. From the monitoring of farming conditions for plant and animal health, registration of the use of pesticides and animal food, the logistics chain to monitor environmental conditions as produce is being transported, and retailers handling of food-all will be connected.

Other Technologies

1.3 M2M towards IoT-the global context

- M2M solutions have been around for decades and are quite common in many different scenarios. While the need to remotely monitor and control assets-personal, enterprise or other-is not new, a number of concurrent things are now converging to create drivers for change not just within the technology industry, but within the wider global economy and society.
- Our planet is facing massive challenges-environmental, social, and economic. The changes that humanity needs to deal with in the coming decades are unprecedented, not because similar things have not happened before during our common history on this planet, but because many of them are happening at the same time. From constraints on natural resources to a reconfiguration of the world's economy, many people are looking to technology to assist with these issues.
- Essentially, therefore, a set of megatrends are combining to create needs and capabilities, which in turn produce a set of IoT Technology and Business Drivers. Figure 1.3
- A *megatrend* is a pattern or trend that will have a fundamental and global impact on society at a macro level over several generations. It is something that will have a significant impact on the world in the foreseeable future. We here imply both game changers as challenges, as well as technology and science to meet these challenges.

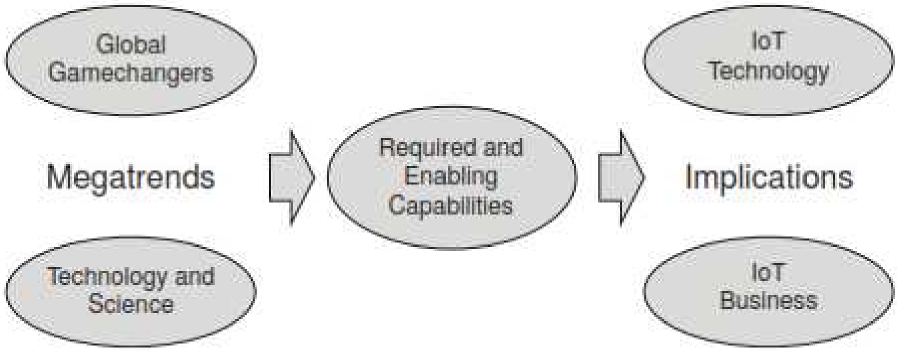

Figure No: 1.3 Megatrends, Capabilities and Implications

1.3.1 Game Changers

- The game changers come from a set of social, economic, and environmental shifts that create pressure for solutions to address issues and problems, but also opportunities to reformulate the manner in which our world faces them.
- There is an extremely strong emerging demand for monitoring, controlling, and understanding the physical world, and the game changers are working in conjunction with technological and scientific advances.
- The transition from M2M towards IoT is one of the key facets of the technology evolution required to face these challenges.
- Some of the global significant game changers
  - **Natural Resource Constraint**
    - The world needs to increasingly do more with less, from raw materials to energy, water or food, the growing global population and associated

economic growth demands put increasing constraints on the use of resources. The use of IoT to increase yields, improve productivity, and decrease loss across global supply chains is therefore escalating.

- **Economic Shifts**
  - The overall economy is in a state of flux as it moves from the post-industrial era to a digital economy. One example of this is found in the move from product-oriented to service-oriented economies
- **Changing Demographics**
  - Many countries will need to deal with an aging population without increasing economic expenditure. As a result, IoT will need to be used, for example, to help provide assisted living and reduce costs in healthcare and emerging “wellcare” systems.
- **Socioeconomic Expectations**
  - Lifestyle and convenience will be increasingly enabled by technology as the same disruption and efficiency practices evident in industries will be applied within people’s lives and homes as well.
- **Climate Change and Environment Impacts**
  - The impact of human activities on the environment and climate has been long debated, but is now in essence scientifically proven. Technology, including IoT, will need to be applied to aggressively reduce the impact of human activity on the earth’s systems.
- **Safety and Security**
  - Public safety and national security becomes more urgent as society becomes more advanced, but also more vulnerable. This has to do both with reducing fatalities and health as well as crime prevention, and different technologies can address a number of the issues at hand
- **Urbanization**
  - Urbanization creates an entirely new level of demands on city infrastructures in order to support increasing urban populations. IoT technologies will play a central role in the optimization for citizens and enterprises within the urban realm, as well as providing increased support for decision-makers in cities.

1.3.2 General technology and scientific trend

- Technological and scientific advances and breakthroughs are occurring across a number of disciplines at an increasing pace.
- Below is a brief description of the science and technology advances that have a direct relevance to IoT.
  - **Material Science**
    - has a large impact across a vast range of industries, from pharmaceutical and cosmetics to electronics.

        - MicroElectroMechanical Systems (MEMS) can be used to build advanced micro-sized sensors like accelerometers and gyroscopes.
        - Emerging flexible and printable electronics will enable a new range of innovations for embedding technology in the real world.
        - From an IoT perspective, these advances in material science will see an increasing range of applications and also a broader definition of what is meant by a sensor.
    - **Complex and Advanced Machinery**
        - Refers to tools that are autonomous or semi-autonomous. Today they are used in a number of different industries, for example, robots and very advanced machinery is used in different harsh environments, such as deep-sea exploration, or in the mining industry in solutions such as Rio Tinto's Mine of the Future.
        - Advanced machines have many modalities, and operate with a combination of local autonomous capabilities as well as remote control. Sensing and actuation are key technologies, and local monitor-control loops for routine tasks are required in addition to reliable communications for remote operations.
        - These systems will continue to evolve and automate tasks today performed by humans- even self-driving cars have started to make headlines thanks to Google.

    - **Energy Production and Storage**
        - is relevant to IoT for two reasons.
        - Firstly, it relates to the global interest of securing the availability of electricity while reducing climate and environmental impacts. Smart Grids, for example, imply micro-generation of electricity using affordable photovoltaic panels. smart grids also require new types of energy storage, both for the grid itself and for emerging technologies such as Electric Vehicles (EVs) that rely on increasingly efficient battery technologies.
        - Secondly, powering embedded devices in Wireless Sensor Networks (WSNs) will increasingly rely on different energy harvesting technologies and also rely on new miniaturized battery technologies and ultra capacitors.

1.3.3 Trends in information and communication technologies

- While significant advances in the fields of Material Science, Advanced and Complex Machinery, and Energy Production and Storage will have an impact on IoT
- **sensors, actuators, and tags function as the digital interfaces**
    - Small-scale and cheap sensors and actuators provide the bridge between the physical realm and ICT systems. Tags using technologies such as RFID provide the means to put electronic identities on any object, and can be cheaply produced.

- **Embedded processing**
    - is evolving not only towards higher capabilities and processing speeds, but also extending towards the smallest of applications.
    - There is a growing market for small-scale embedded processing such as 8-, 16-, and 32-bit microcontrollers with on-chip RAM and flash memory, I/O capabilities, and networking interfaces such as IEEE 802.15.4 that are integrated on tiny System-on-a-Chip (SoC) solutions.
- **Instant access to the Internet**
    - virtually everywhere today, mainly thanks to wireless and cellular technologies and the rapid deployment of cellular 3G and 4G or Long Term Evolution (LTE) systems on a global scale.
    - These systems provide ubiquitous and relatively cheap connectivity with the right characteristics for many applications, including low latency and the capacity to handle large amounts of data with high reliability.
- **Software Architectures**
    - Software architectures have undergone several evolutions over the past decades, in particular with the increasing dominance of the web paradigm.
    - Software architecture refers to the high level structures of a software system, the discipline of creating such structures, and system. Each structure comprises software elements, relations among them, and properties of both elements and relations
- **Service Oriented Approach (SOA)**
    - A service-oriented architecture (SOA) is a style of software design where services are provided to the other components by application components, through a communication protocol over a network.

- **Open APIs**
    - Open APIs relate to a common need to create a market between many companies, as is the case in the IoT market. Open APIs permit the creation of a fluid industrial platform, allowing components to be combined together in multiple different ways by multiple developers with little to no interaction with those who developed the platform, or installed the devices.
    - Without Open APIs, a developer would need to create contracts with several different companies in order to get access to the correct data to develop the application.
    - The transaction costs associated with establishing such a service would be prohibitively expensive for most small development companies; they would need to establish contracts with each company for the data required, and spend time and money on legal fees and business development with each individual company.

- **Virtualization**
  - has many different facets and has gained a lot of attention in the past few years, even though it has been around for a rather long time.

- **Cloud Computing**
  - Cloud computing allows elasticity in deployment of services and enables reaching long-tail applications in a viable fashion.
  - Cloud computing also has the benefit of easing different businesses to interconnect if they are executing on the same platform.

- **Big Data**
  - Big data, which refers to the increasing number and size of data sets that are available for companies and individuals to collect and perform analysis on.

- **Decision support**
  - Knowledge representation across domains and heterogeneous systems are also important, as are semantics and linked-data.

1.3.3.1 Capabilities

- These capabilities address several aspects such as cost efficiency, effectiveness and convenience; being lean and reducing environmental impact; encouraging innovation; and in general, applying technology to create more intelligent systems, enterprises, and societies.
- The aforementioned ICT developments provide us with a rich toolbox to address these different aspects in general, and as part of that, IoT in particular.
- While M2M today targets specific problems with tailored, siloed solutions, it is clear that emerging IoT applications will address the much more complex scenarios of large-scale distributed monitor and control applications.
- For example, Smart City solutions: here there is a clear need for integration of multiple disparate infrastructures such as utilities, including district heating and cooling, water, waste, and energy, as well as transportation such as road and rail.
- Each of these infrastructures has multiple stakeholders and separate ownership even though they operate in the same physical spaces of buildings, road networks, and so on.
- The optimization of entire cities requires the opening up of data and information, business processes, and services at different levels of the disjoint silos, creating a common fabric of services and data relating to the different infrastructures.
- IoT will allow more assets of enterprises and organizations to be connected, thus allowing a tighter and more prompt integration of the assets into business processes and expert systems.
- Simple machines can be used in a more controlled and intelligent manner, often called “Smart Objects.” These connected assets will generate more data and information, and will expose more service capabilities to ICT systems.

- As society operations involve a large number of actors taking on different roles in providing services, and as enterprises and industries increasingly rely on efficient operations across ecosystems, cross value chain and value system integration is a growing need.
- These sorts of collaboration scenarios will become increasingly important as industries, individuals, and government organizations work together to solve complex problems involving multiple stakeholders.
- The open and collaborative nature of IoT means methods are required to publish and discover data and services, as well as means to achieve semantic interoperability, but also that care needs to be given to trust, security, and privacy.
- As we come to increasingly rely on ICT solutions to monitor and control assets, physical properties of the real world require not just increased levels of cybersecurity, but what can be referred to as cyber-physical security. In the use of the Internet today, it is possible to exact financial damage via breaking into information technology (IT) systems of companies or bank accounts of individuals.
- This raises requirements for trust and security to be correctly implemented in IoT systems.

1.3.4 Implications for IoT

- Having gained a better understanding of capabilities needed, as well as how technology evolution can support these needs.
- There is already a trend of moving away from vertically oriented systems, or application-specific silos, towards a horizontal systems approach.
- The use of the TCP/IP stack towards IoT devices represents another horizontal point in an M2M and IoT system solution, and is something driven by organizations like the IETF and the IP for Smart Objects (IPSO) Alliance.
- In the M2M device area, there is an emerging consolidation of technologies where solutions across different industry segments traditionally rely on legacy and proprietary technologies.
- Currently within industry segments there is technology fragmentation, one example being Building and Home Automation and Control with legacy technologies like BACnet, Lonworks, KNX, Z-Wave, and ZigBee.
- Where there is a requirement for integration across multiple infrastructures and of a large set of different devices, as well as data and information sharing across multiple domains, there is a clear benefit from a horizontal systems approach with at least a common conceptual interoperability made available, and a reduced set of technologies and protocols being used.
- M2M is point problem-oriented, resulting in point solutions where devices and applications are highly dedicated to solving a single task.
- M2M devices are for this reason many times highly application-specific, and reuse of devices beyond the M2M application at hand is difficult, if at all possible.

- Benefits will be achieved if an existing device can be used in a variety of applications, and likewise if a specific application can use a number of different deployed devices.
- Here we see a shift from application-specific devices towards application-independent devices
- Clear benefits come from relying on the web services paradigm, as it allows easy integration in SOAs and attracts a larger application developer community.
- Even though M2M has been around for many years, recent years have seen a tremendous interest in M2M across industries, primarily the telecom industry.
- This comes from the fact that both devices and connectivity have become viable for many different applications, and M2M today is centered on devices and connectivity.
- For IoT there will be a shift of focus away from device- and connectivity-centricity towards services, data, and intelligence.

1.3.5 Barriers and Concerns

- With the IoT, the first concern that likely comes to mind is the compromise of privacy and the protection of personal integrity. The use of RFID tags for tracing people is a raised concern. With a massive deployment of sensors in various environments, including in smartphones, explicit data and information about people can be collected, and using analytics tools, users could potentially be profiled and identified even from anonymized data.
- The reliability and accuracy of data and information when relying on a large number of data sources that can come from different providers that are beyond one’s own control is another concern.

1.4 A use case example

- Measuring human stress can be done using sensors. Two common stress measurements are heart rate and galvanic skin response (GSR), and there are products on the market in the form of bracelets that can do such measurements.
- A higher intensity can be the cause of stress, but can also be due to exercise.

1.5 Differing Characteristics

- The transition from M2M towards an IoT is mainly characterized by moving away from the mentioned closed-silo deployments towards something that is characterized by openness, multipurpose, and innovation.

Aspect	**M2M**	**IoT**
Applications and Services	Point problem driven	Innovation driven
	Single application-single device	Multiple applications-multiple devices
	Communication and device centric	Information and service centric
	Asset management driven	Data and information driven
Business	Closed business operations	Open market place
	Business objective driven	Participatory community driven
	B2B	B2B, B2C
	Established value chains	Emerging ecosystems
	Consultancy and Systems Integration enabled	Open Web and as-a-Service enabled
	In-house deployment	Cloud deployment
Technology	Vertical system solution approach	Horizontal enabler approach
	Specialized device solutions	Generic commodity devices
	De facto and proprietary	Standards and open source
	Specific closed data formats and service descriptions	Open APIs and data specifications
	Closed specialized software Development	Open software development
	SOA enterprise integration	Open APIs and web development