Everything you Wanted to Know about Smart Cities

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More Info: http://www.smohanty.org
Talk: Outline

- Smarty City Drivers
- Smarty City Components
- Smarty City Technologies
- Design and Operation of Smarty Cities
- Challenges and Research on Smarty Cities
- Tools and Solutions for Smarty Cities
- Initiatives on Smarty Cities
- Standards for Smarty Cities
- Conclusions and Future Directions
Drivers
Population Trend

- 2025: 60% of world population will be urban
- 2050: 70% of world population will be urban

Source: [http://www.urbangateway.org](http://www.urbangateway.org)
 Issues Challenging Sustainability

➢ Energy crisis

Sources of Electricity Generation
United States - 2016

- 33.8%
- 30.4%
- 19.7%
- 6.5%
- 5.5%
- 1.5%
- 2.6%
Issues Challenging Sustainability

➢ Pollutions
The Problem

- Uncontrolled growth of urban population
- Limited natural and man-made resources

Source: https://humanitycollege.org
The Solution

Smart Cities: For effective management of limited resource to serve largest possible population to improve:
- Livability
- Workability
- Sustainability
Smart Cities: Formal Definition

Definition - 1: A city “connecting the physical infrastructure, the information-technology infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city”.

Definition - 2: “A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operations and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social and environmental aspects”.

Source: Mohanty 2016, CE Magazine July 2016
Other drivers …

- Managing vital services
  - Waste management
  - Traffic management
  - Quality Healthcare
  - Crime prevention

- Making the city competitive
  - Investment
  - Tourism

- Technology push
  - IoT, CPS, Sensor, Wireless

Source: Sangiovanni-Vincentelli 2016, ISC2 2016
Components
A smart city can have one or more of the smart components.

Source: Mohanty 2016, CE Magazine July 2016
Smart Transportation

Smart Transportation Features:

- Effective traffic management
- Real-time vehicle tracking
- Vehicle safety – Automatic brake
- Vehicle-to-Vehicle communication
- Better scheduling of train, aircraft
- Easy payment system

“The smart transportation system allows passengers to easily select different transportation options for lowest cost, shortest distance, or fastest route.”

Source: Mohanty 2016, CE Magazine July 2016
Understanding the concept of Smart Healthcare is crucial. It combines the Internet of Things (IoT) with healthcare services to provide quality and sustainable healthcare with limited resources, anywhere, anytime.

Key components of Smart Healthcare include:
- Smart Hospitals
- Emergency Response
- Smart Homes
- Smart Infrastructure
- Smart Gadgets
- On-body Sensors
- Robots
- Headbands with Embedded Neurosensors
- Skin Patches
- Fitness Trackers

Quality and sustainable healthcare with limited resources, anywhere, anytime.

Source: Mohanty 2016, CE Magazine July 2016

Sethi 2017: JECE 2017
### Smart Healthcare: Smart-Walk

**Sensor System**
- Piezoelectric Accelerometer
- Walking Frequency
- Accelerometer Variance

**Machine Learning Algorithms**
- Data Preprocessing
- Filtering
- Detection Phase

**Information Sharing**
- Assistance to users

**Automated Physiological Monitoring System**

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<table>
<thead>
<tr>
<th>Research Works</th>
<th>Method</th>
<th>Features considered</th>
<th>Activities</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>This Work</strong></td>
<td>Adaptive algorithm based on feature extraction (WEKA)</td>
<td>Step detection and Step length estimation</td>
<td>Walking, sitting, standing, etc.</td>
<td>97.9</td>
</tr>
</tbody>
</table>

Source: Mohanty ICCE 2018

10291 Instances Grouped Under 6 Activities - Kaggle

![Pie chart showing activity distribution](chart.png)

Walking upstair: 15%
Walking downstairs: 13%
Walking: 17%
Sitting: 17%
Laying: 19%
Standing: 19%
Smart Healthcare: Smart-Log

- Smart Sensor Board
- Data Acquisition
- Future Meal Predictions

USDA National Nutrient Database for Standard Reference is used for nutrient values of 8791 items.

8172 user instances were considered

<table>
<thead>
<tr>
<th>Research Works</th>
<th>Food Recognition Method</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>This Work</td>
<td>Mapping nutrition facts to a database</td>
<td>98.4</td>
</tr>
</tbody>
</table>

Source: Mohanty ICCE 2018
Smart Healthcare: Ambulatory Health Monitoring System

- **Array of Sensors**
  - pH Sensitivity
  - Temperature Sensor
  - Gyroscope
  - Proximity Sensor

- **Human Body**
  - Communication Environment: Intra Body Communication (HBC)
  - BCC Coupling method: Capacitively coupled
  - Frequency range of operation: 1 – 100 MHz
  - Power consumption: 3.14 mW (31% less)

**Characteristics**

<table>
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<tr>
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<th>Values</th>
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Source: Mohanty iNIS 2016

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Smart Healthcare: Thyroid Monitoring System

High BBT → Possible Hyperthyroidism
Low BBT → Possible Hypothyroidism

Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature range</td>
<td>25°C to 40°C</td>
</tr>
<tr>
<td>Power Supply</td>
<td>4 V</td>
</tr>
<tr>
<td>Accuracy</td>
<td>± 0.1°C</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>28.5 μW</td>
</tr>
<tr>
<td>Frequency range</td>
<td>42.906 – 43.5 MHz</td>
</tr>
</tbody>
</table>

Source: Mohanty EuroSimE 2016

Continuously monitors the basal body temperature (BBT)
Smart Healthcare: Epileptic Seizure Detector

Parameter | Value
--- | ---
Seizure Frequency (Minimum) | 5 Hz
Seizure Frequency (Minimum) | 25 Hz
Voltage Level Detector (Avg. Lower Threshold) | 210 mV
Voltage Level Detector (Avg. Upper Threshold) | 380 mV
Total power consumption | 6.18 µW

Source: Mohanty ICCE 2018
Smart Energy

Internet of Energy

ICT/IoT Role:
- Management of energy usage
- Power generation dispatch for solar, wind, etc.
- Better fault-tolerance of the grid
- Services for plug-in electric vehicles (PEV)
- Enhancing consumer relationships

Quality, sustainable, uninterrupted energy with minimal carbon footprint.

Source: Mohanty 2016, CE Magazine July 2016
Smart Agriculture

Climate-Smart Agriculture Objectives:
- Increasing agricultural productivity
- Resilience to climate change
- Reducing greenhouse gas

Source: http://www.fao.org

Automatic Irrigation System

Source: Maurya 2017: CE Magazine July 2017

FUTURE FARMS
small and smart

SURVEY DRONES
Aerial drones survey the fields, mapping weeds, yield and soil variation. This enables precise application of inputs, mapping spread of pernicious weed blackgrass could increasing Wheat yields by 2-5%.

FLEET OF AGRIBOTS
A herd of specialised agribots tend to crops, weeding, fertilising and harvesting. Robots capable of microdust application of fertiliser reduce fertiliser cost by 99.9%.

FARMING DATA
The farm generates vast quantities of rich and varied data. This is stored in the cloud. Data can be used as digital evidence reducing time spent completing grant applications or carrying out farm inspections saving on average £5,500 per farm per year.

TEXTING COWS
Sensors attached to livestock allowing monitoring of animal health and wellbeing. They can send texts to alert farmers when a cow goes into labour or develops infection increasing herd survival and increasing milk yields by 10%.

SMART TRACTORS
GPS controlled steering and optimised route planning reduces soil erosion, saving fuel costs by 10%.

Source: http://www.nesta.org.uk/blog/precision-agriculture-almost-20-increase-income-possible-smart-farming

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“Smart government integrates information, communication and operational technologies to planning, management and operations across multiple domains, process areas and jurisdictions to generate sustainable public value.”

-- http://www.gartner.com


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Technologies
Smart Cities

Smart Cities ⇐

Regular Cities
+ Information and Communication Technology (ICT)
+ Smart Components
+ Smart Technologies
Smart Cities: 3 Is

Instrumentation

Intelligence

Interconnection

The 3Is are provided by the Internet of Things (IoT).

Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation
Smart Infrastructure

Cyber Physical System (CPS)

IoT is the Backbone Smart Cities.

Source: Mohanty 2016, CE Magazine July 2016
IoT: Architecture

- Overall Architecture:
  - A configurable dynamic global network of networks
  - Systems-of-Systems

Source: Mohanty 2016, EuroSimE 2016 Keynote Presentation
IoT: The Things

- EveryTHING is connected
- EveryTHING emits signals
- EveryTHING communicates

The “Things” refer to any physical object with a device that has its own IP address and can connect and send/receive data via network.
Sensor Technology: Wide Variety

100s of Sensors


Thing ↔ Sensor
+ Device with its own IP address
Communications Technology: Wide Variety

- NFC
- Bluetooth
- 4G LTE
- DSL

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Computing Technology: Cheaper

Raspberry Pi

Arduino

LattePanda

Source: http://www.lattepanda.com

Source: https://www.sparkfun.com/products/13678
Memory Technology: Cheaper, Larger, Faster, Energy-Efficient

Smaller Geometry, Higher Bandwidth, Higher Density, Less Power

Memory Size exponentially doubles each 18th month

## Energy Storage: High Capacity and Efficiency

<table>
<thead>
<tr>
<th>Battery</th>
<th>Conversion Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Li-ion</td>
<td>80% - 90%</td>
</tr>
<tr>
<td>Lead-Acid</td>
<td>50% - 92%</td>
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<tr>
<td>NiMH</td>
<td>66%</td>
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**Intelligent Battery**

![Intelligent Battery Image](image)

**Battery Conversion Efficiency**

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Efficiency Range</th>
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**Figure 1: IntellBatt Architecture**

Mohanty 2018: ICCE 2018

**Battery Conversion Efficiency**

- **Li-ion**: 80% - 90%
- **Lead-Acid**: 50% - 92%
- **NiMH**: 66%

**IntellBatt**

- **Cell 1**
- **Cell 2**
- **Cell n**

**Intelligent Battery Components**

- **SMBus**
- **IntellBatt**
- **Battery-Operated Portable System**

**Lithium Polymer Battery**

- **Voltage**: 3.7V
- **Model**: NO MOTO L6
- **Super capacitor**

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Cashless Payment Technology: An Example

Source: Mohanty 2017, CE Magazine Jan 2017
Machine Learning Technology

Artificial Intelligence

Tensor Processing Unit (TPU)

Smart City Use:
- Better decision
- Faster response

Source: http://transmitter.ieee.org/impact-aimachine-learning-iot-various-industries/

Source: https://fossbytes.com/googles-home-made-ai-processor-is-30x-faster-than-cpus-and-gpus/

April 2017

Smart Cities by Prof./Dr. Saraju P. Mohanty
Virtual and Augmented Reality Technology

Virtual Reality

Augmented Reality

Smart City Use:
- Healthcare - Therapy, Surgery
- Tourism - Recreate History
- Entertainment - Movies

# Technology in Smart Cities

<table>
<thead>
<tr>
<th>Smart Cities Technology</th>
<th>% of Cities Adopting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geospatial/mapping</td>
<td>69</td>
</tr>
<tr>
<td>Virtualization</td>
<td>67</td>
</tr>
<tr>
<td>Performance benchmarking</td>
<td>60</td>
</tr>
<tr>
<td>Transaction processing</td>
<td>58</td>
</tr>
<tr>
<td>Project management</td>
<td>57</td>
</tr>
<tr>
<td>Consolidation</td>
<td>57</td>
</tr>
</tbody>
</table>

Design and Operation
Smart Cities: Design Cycle

1. Set Vision for Smart City Venture
2. Identify Smart City Targets
3. Achieve Political Cohesion
4. Build Smart City
5. Measure Smart City’s Progress
6. Ensure Accountability and Responsibility

Source: Paolo Gemma 2016, ISC2 2016
Smart City Design: Vision and Target

1. Set Vision for Smart City Venture

2. Identify Smart City Targets

Source: Paolo Gemma 2016, ISC2 2016
3. Achieve Political Cohesion

- Academia, Research Organizations and Specialized Bodies
- National and Regional Governments
- Municipalities, City Council and City Administration

4. Build Smart City

- ICT Companies
- City Service Companies
- Urban Planners
- Standardization Bodies
- Industry Associations

- Utility Providers
- Citizens and Citizen Organizations
- Non-Governmental Organization (NGO)

Source: Paolo Gemma 2016, ISC2 2016
Smart City Design: Sustainable Goals

5. Measure City’s Progress

Dimensions of Key Performance Indicators (KPIs)

- Environment
  - Air quality
  - Water
  - Noise
  - Biodiversity
  - Energy
  - Environmental quality

- Society and Culture
  - Education
  - Health
  - Safety
  - Housing
  - Culture
  - Social inclusion

- Economy
  - Innovation
  - Employment
  - Trade
  - Productivity
  - Physical infrastructure
  - ICT infrastructure and Access/Usage
  - Public Sector

Source: Paolo Gemma 2016, ISC2 2016
Smart City Design: Building Trust

6. Ensure Accountability and Responsibility

- Citizen-Centric
- Smart Tools
- Data-Driven Decision
- Cost Effective
- Collaborative
- Responsive
- Accountable
- Transparent

Source: Paolo Gemma 2016, ISC2 2016

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Smart City Design: Verticals

- VLSI
- Embedded Systems
- Artificial Intelligence
- IoT
- Smart City Components
- Big Data
- Machine Learning
- Cloud Computing
Smart City Design: ICT/IoT is Key

Source: https://www.pinterest.com/source/hitachi.com/
Challenges and Research
Smart City: Selected Design Challenges

Source: Mohanty 2016, CE Magazine July 2016
Cost

“Cities around the world could spend as much as $41 trillion on smart tech over the next 20 years.”

Design Cost

- The design cost is a one-time cost.
- Design cost needs to be small to make a smart city realization possible.

Operational Cost

- The operations cost is that required to maintain the smart city.
- A small operations cost will make it easier for cities to operate in the long run with minimal burden on the city budget.
## Cost: Technology

<table>
<thead>
<tr>
<th>Smart Cities Technology</th>
<th>% Net Increase in All Cities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloud apps</td>
<td>86</td>
</tr>
<tr>
<td>Mobile devices</td>
<td>66.6</td>
</tr>
<tr>
<td>Business applications</td>
<td>61.9</td>
</tr>
<tr>
<td>Outsourcing</td>
<td>53.8</td>
</tr>
<tr>
<td>Security &amp; privacy</td>
<td>53.8</td>
</tr>
</tbody>
</table>

Energy Consumption

Energy Consumption by Sector (2015)

- Commercial: 4.07 QBTu (4%)
- Residential: 6.50 QBTu (7%)
- Industrial: 21.22 QBTu (22%)
- Transportation: 27.63 QBTu (28%)
- Electricity: 38.11 QBTu (39%)

Data Center Power Usage

Energy Usage in the U.S. Residential Sector in 2015

- Space Heating: 27.3%
- Water Heating: 13.1%
- Space Cooling: 11.8%
- Other: 20.8%
- Cooking: 2.7%
- Television: 4.2%
- Clothes Washers/Dryers & Dishwashers: 5%
- Refrigerators & Freezers: 6.3%
- Lighting: 7.2%

Source:

Individual Level: Imagine how often we charge our portable CE!
Energy Efficient Sensors, Components, and Systems

Typical CE System

During GSM Communications

During WiFi Communications

Software Components

General Purpose Digital Processor

Digital Signal Processor

Data Converter

Graphics Core

Baseband Telecommunication (GSM, CDMA)

Wireless LAN Bluetooth

Image Sensor

IEEE Distinguished Lecture. IEEE CE Society Webinar.

Smart Cities by Prof./Dr. Saraju P. Mohanty

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Energy Storage Efficiency and Safety

- Boeing 787’s across the globe were grounded in 2016.

One 787 Battery: 12 Cells / 32 V DC
Source: [http://www.newairplane.com](http://www.newairplane.com)
Security, Privacy, and Copyright

Hardware Trojan

IEEE Consumer Electronics Magazine
Feeling Secure?
Examining Hardware IP Protection and Trojans
July 2017
Cybercrime damage costs to hit $6 trillion annually by 2021
Cybersecurity spending to exceed $1 trillion from 2017 to 2021

Failure Tolerance and Resilience

Power Failure

ICT Failure
Bigdata in Smart Cities

Sensors, social networks, web pages, image and video applications, and mobile devices generate more than 2.5 quintillion bytes data per day.

Source: Mohanty 2016, CE Magazine July 2016
Tools and Solutions
Market Opportunities

- “The 100 largest cities in the world produce 25 per cent of the planet’s wealth, which will be smart cities”.
- “New research predicts that global urbanization will fuel smart cities market growth by nearly 19% over the next 10 years.”
- Together these 4 sectors make up 70 per cent of the total opportunity (This is trillions of dollars opportunity):
  - Energy
  - Building automation
  - Transportation and logistics
  - Financial services.

Smart Cities Simulator

- Simulator is needed to verify and characterize a smart city component (or a cyber physical system (CPS)), before deployment.
- Smart city is too large, complex, and diverse.
- For different components of smart cities, different simulator may be needed.
Smart Cities Simulator: CUPCARBON

About
- CUPCARBON is a smart city and Internet of Things Wireless sensor network simulator (SCI-WSN)

Objective
- Design, Visualize, Debug
- Validate distributed algorithms
- Create environmental scenarios

Environments
- Design of mobility scenarios and the generation of natural events such as fires and gas as well as the simulation of mobiles such as vehicles and flying objects (e.g. UAVs, insects, etc.).
- A discrete event simulation of WSNs which takes into account the scenario designed on the basis of the first environment.

Source: http://www.cupcarbon.com/
**Smart Cities Simulator: UrbanSim**

UrbanSim is a simulation platform for supporting planning and analysis of urban development, incorporating the interactions between land use, transportation, economy, and environment.

Source: http://www.urbansim.com/home
Industry Solutions: IBM

IBM Intelligent Operations Center for Smarter Cities
Industry Solutions: Cisco

- Cisco Smart+Connected Communities have solutions along 8 tracks:
  - Smart+Connected Real Estate
  - Smart+Connected Utilities
  - Smart+Connected Transportation
  - Smart+Connected Safety & Security
  - Smart+Connected Learning
  - Smart+Connected Health
  - Smart+Connected Government
  - Smart+Connected Sports and Entertainment
Initiatives
IEEE Smart Cities

IEEE Technical Community created: [http://smartcities.ieee.org](http://smartcities.ieee.org)

The IEEE International Smart Cities Conference (ISC2) is the flagship event of the IEEE Smart Cities Initiative.

IEEE Smart Cities initiative: IEEE Core Smart Cities program recognizes/helps cities which establish and invest both human/financial capital into smart city plans.

Current IEEE Core Smart Cities: Casablanca, Morocco; Guadalajara, Mexico; Kansas City, USA; Trento, Italy; and Wuxi, China.

IEEE Affiliated Smart Cities program: Allow more cities to participate in and enjoy benefits of the IEEE Smart Cities program and network.

UN Initiative: United 4 Smart Sustainable Cities (U4SSC)

U4SSC is a global platform for smart city stakeholders which advocates for public policy to encourage the use of ICTs to facilitate the transition to smart sustainable cities.

Source: Paolo Gemma 2016, ISC2 2016

Setting the Framework

- Urban Planning
- Policy, Standards and Regulation
- Key Performance Indicators

Connecting Cities and Communities

- Smart Living
- Smart Mobility
- Smart Environment

Enhancing Innovation and Participation

- Smart Governance
- Smart People
- Smart Economy
Smart Cities Council

The Smart Cities Council is a network of leading companies advised by top universities, laboratories and standards bodies.

Help cities become smarter through a combination of advocacy and action:

- Readiness Guides
- Financing templates and case studies
- Policy frameworks and case studies
- Visibility campaigns
- Regional networking events

Source: http://smartcitiescouncil.com/
Smart Cities Connect

Smart Cities Connect is the largest city-first membership organization for global smart city leaders.

This group is advancing the growth of smart cities by working together, discussing projects, and sharing common goals and challenges.

Smart Cities Connect Conference and Expo brings together over 200 cities and their respective leadership.

Source: http://smartcitiesconnect.org/
USA: National Science Foundation (NSF)

- Smart and Connected Communities (S&CC)
- Smart and Connected Health (SCH)
- Smart and Autonomous Systems (S&AS)

Source: https://www.nsf.gov
India Smart Cities Mission

- By Ministry of Urban Development, Govt. of India
- With increasing urbanization, urban areas are expected to house 40% of India’s population and contribute 75% of India’s GDP by 2030.
- 20 Smart Cities in 1st round: Bhubaneswar, Pune, Jaipur, Surat, Kochi, Ahmedabad, Jabalpur, Visakhapatnam, Solapur, Davanagere, Indore, New Delhi Municipal Council, Coimbatore, Kakinada, Belagavi, Udaipur, Guwahati, Chennai, Ludhiana, Bhopal
- Two Type of Value Capture
  - Project-based
  - Area-based
- Statistics:
  - Total Urban Population Impacted - 72,266,232
  - Total Cost of Projects - INR 1,317,620 Million
  - Total Area Based Development Cost - INR 1,056,210 Million

Smart Cities: Case Study: Barcelona

- Sensors monitor traffic levels, road pollution, crowds
- Sensors monitor the weather
- Sensors measure rainfall and analyze irrigation levels in the ground
- LED lighting arrangements

Source: http://www.ioti.com/smart-cities/world-s-5-smartest-cities

Source: http://luxreview.com/article/2017/02/-what-are-the-top-five-smart-cities-in-the-world-
Smart Cities: Case Study: San Francisco

- LEED-certified buildings than any other in the USA and a connected city initiative
- Smart transportation: Smart parking, Contactless payments
- LED lighting arrangements.

Source: http://luxreview.com/article/2017/02/-what-are-the-top-five-smart-cities-in-the-world-
Standards
Standards: Why

- To determine entry points for investment in city markets and make informed decisions through data analysis
- To benchmark investments and monitor progress
- To evaluate the “impact” of infrastructure projects on the sustainability and efficiency of the city
- To build smart and sustainable cities
- To evaluate the investment in comparative perspective across cities nationally and globally
- To strengthen the effectiveness of city governance

Source: https://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2015/SSC/S6-MrDWelsh_MrFDadaglio.pdf
Standards: What

- International Organization for Standards (ISO) initiatives.
- International Telecommunication Union (ITU), United Nations specialized agency on ICT has been working.
- International Electrotechnical Commission (IEC) has initiatives.
- IEEE has been developing standards for smart cities for its different components including smart grids, IoT, eHealth, and intelligent transportation systems (ITS).
- Selected indicators: economy, education, energy, and environment.
Standards: ISO

- ISO 37120 Sustainable development & resilience of communities - Indicators for city services & quality of life
- ISO/TR 37150 Smart community infrastructures - Review of existing activities relevant to metrics
- ISO 37101 Sustainable development of communities -- Management systems -- Requirements with guidance for resilience and smartness
- ISO 37102 Sustainable development & resilience of communities – Vocabulary
- ISO/TR 37121 Inventory & review of existing indicators on sustainable development & resilience in cities
- ISO/TS 37151 Smart community infrastructures -- Principles and requirements for performance metrics
- ISO/TR 37152 Smart community infrastructures -- Common framework for development & operation

Source: https://www.itu.int/en/ITU-D/Regional-Presence/ArabStates/Documents/events/2015/SSC/S6-MrDWelsh_MrFDadaglio.pdf
Standards: IEEE

Standards activities are underway:

- Smart Grid
- Cloud Computing
- Internet of Things (IoT)
- Intelligent Transportation
- eHealth

Conclusions
Conclusions

- Smart cities is not a technological trend, rather it is a necessity.
- Smart cities technology is an ongoing R & D.
- Multi-Front research on smart cities from academia and industries are in full swing.
- Smart cities still need significant maturity for effective design and operation.
- R & D seems to be in right direction.
Future Research

- Energy-efficient, accurate sensors
- Security
- Privacy
- IP or content protection
- Energy efficiency
- Big data processing
- Efficient, Safer Battery
- Larger, cheaper, faster memory
Thank You !!!

Slides Available at:
http://www.smohanty.org

Hardwares are the drivers of the civilization, even softwares need them.

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