IoT & Health:

An Initial Survey and Discussion of the Challenges and Opportunities

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Introduction

Agenda

- Introduction
- What is IoT?
- Findings 1. Benefits of IoT
- Findings 2. IoT Process and Systems Challenges
- Findings 3. IoT Capabilities
- Findings 4. Support for IoT
- Findings 5. Future of IoT
- Conclusions

Introduction

Research Aims

Qualitative Pilot Study of:

a) the current understanding and use of IoT in health
b) what capabilities are most sought after and what are the most promising applications of IoT in health?
c) what are the problems in both the use of IoT and in preparing and convincing health management of the opportunities?

Introduction

- Twenty examples of IoT systems were studied based on contacts and questionnaire responses with Chief and Senior Medical/Project Officers of NHS Trusts or specific IoT based companies

Ref	IoT Case
1	Remote Monitoring and Telecare of Chemotherapy Patients Vital signs
2	Insulin Pump Monitoring
3	Cardiothoracic Implanted Device monitoring
4	Remote Acute Patient State Monitoring
5	Chronic Obstructive Pulmonary Disease (COPD) state monitoring
6a	Teletracking – Auto- info on Discharge of patients
6b	Theatre resource management, monitoring theatre usage and state
7	Home monitoring of patients with long term conditions
8	Automated patient alerts
9	Neurological conditions (automatic physician alerts)
10	Enabling patients to triage themselves and book themselves into care
11	Monitoring of clinician hand washing
12	Monitoring of patients, clinicians and operating theatre process
13	Monitoring of battery defibrillators vs failure/ theft
14	Monitoring aged patients daily routines
15a	Monitoring drug storage temp and conditions
15b	Monitoring of shipments of vaccines within a temperature range
16	Monitoring patient blood glucose and blood pressure
17	Tracking patients and nurses, monitoring room access, bp etc, controlling/optimising diabetes and urinary infections
18	Medical emergency backpack location and signal optimisation

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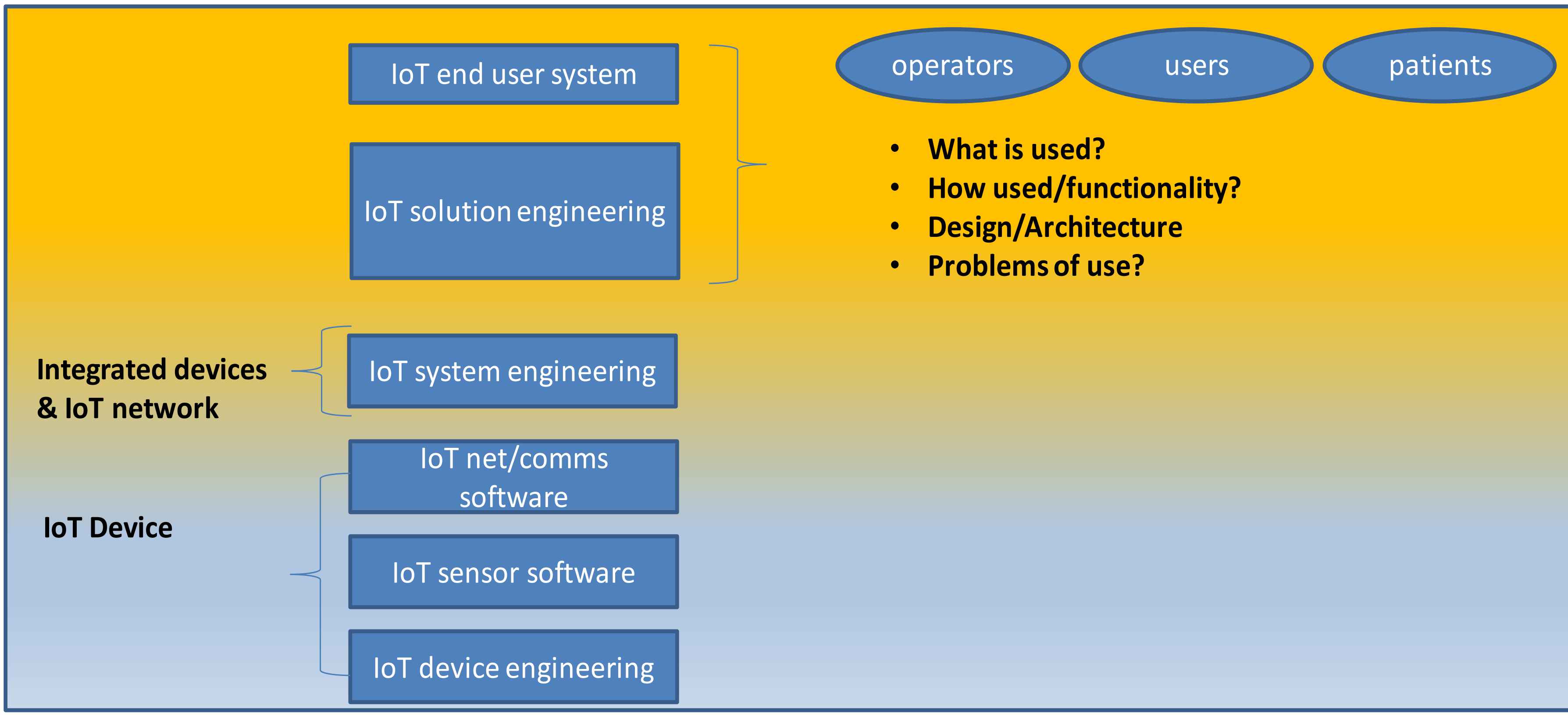
Questionnaire Areas:

- 1: Use of IoT –case examples, benefits and barriers
- 2: IoT Process and system design challenges
- 3: IOT capabilities
- 4: Support for IoT – procurement, use of consultants, culture/risks/ issues

Introduction

Focus Area: IoT Solution Design/Operations



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Study Limitations

- A pilot study
- Limited detail due to access and commercial confidentiality
- A snapshot of the general state of the area and opportunities
- Qualitative focus – to be followed up by a quantitative study

What is IoT?

What is IoT?

'virtually every physical thing in this world can also become a computer that is connected to the Internet' (Fleisch., 2010)

A "thing" is any ***object with embedded electronics*** *that can transfer data over a network — without any human interaction. (IBM Watson)*

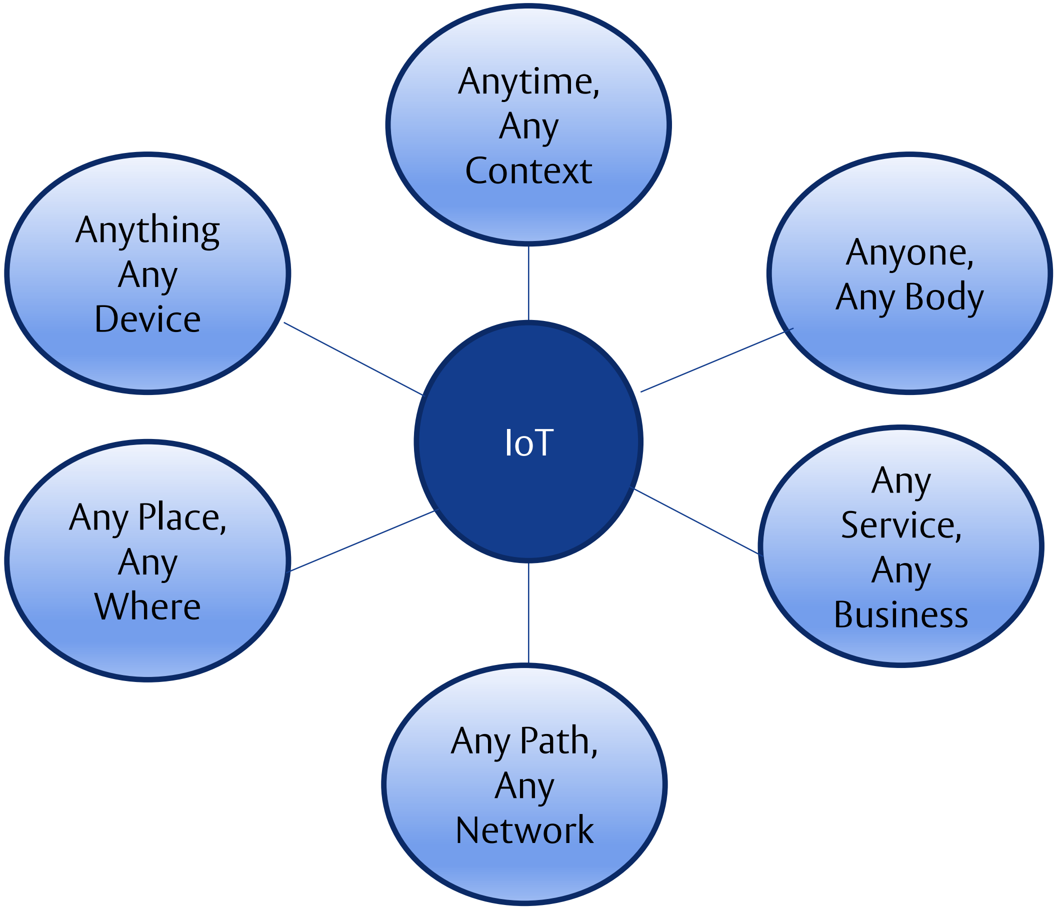
Machine-to-Machine (M2M)" or "Human-to-Machine (H2M)" **communication**

'the extension of the Internet and the Web into the physical realm, by the means of spatially distributed systems; devices with embedded identification, sensing actuation capabilities' *(Miorandi et al., 2012)*

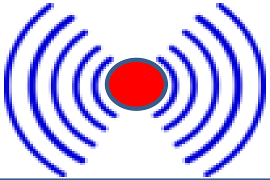
What is IoT?

IoT creates a better quality of life by connecting "Things", which can be patients and medical staff, objects, medical equipment and systems and integrating them using web technology and connectivity

(Kamalanathan et al., 2013)



What is IoT?



Web communications

object

\+ 

sensor

\+/or:

actuator

\+ 

processor

\+ identity

Data storage

What is IoT?

Examples

Baby tracker

Drug pump

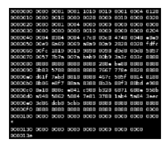
Diabetic Care

What is IoT?

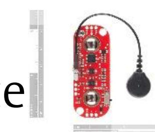
IoT

- Devices with physical interfaces to the real world

- Structured data input through sensors



- Tiny input/output device



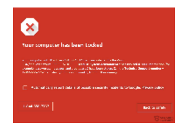
- Machine and or human/environment drivers

- Real time action and decision control

(Based on Blaauw et al., 2014)

Traditional Computing Platforms

- Devices use human interfaces and interpretations



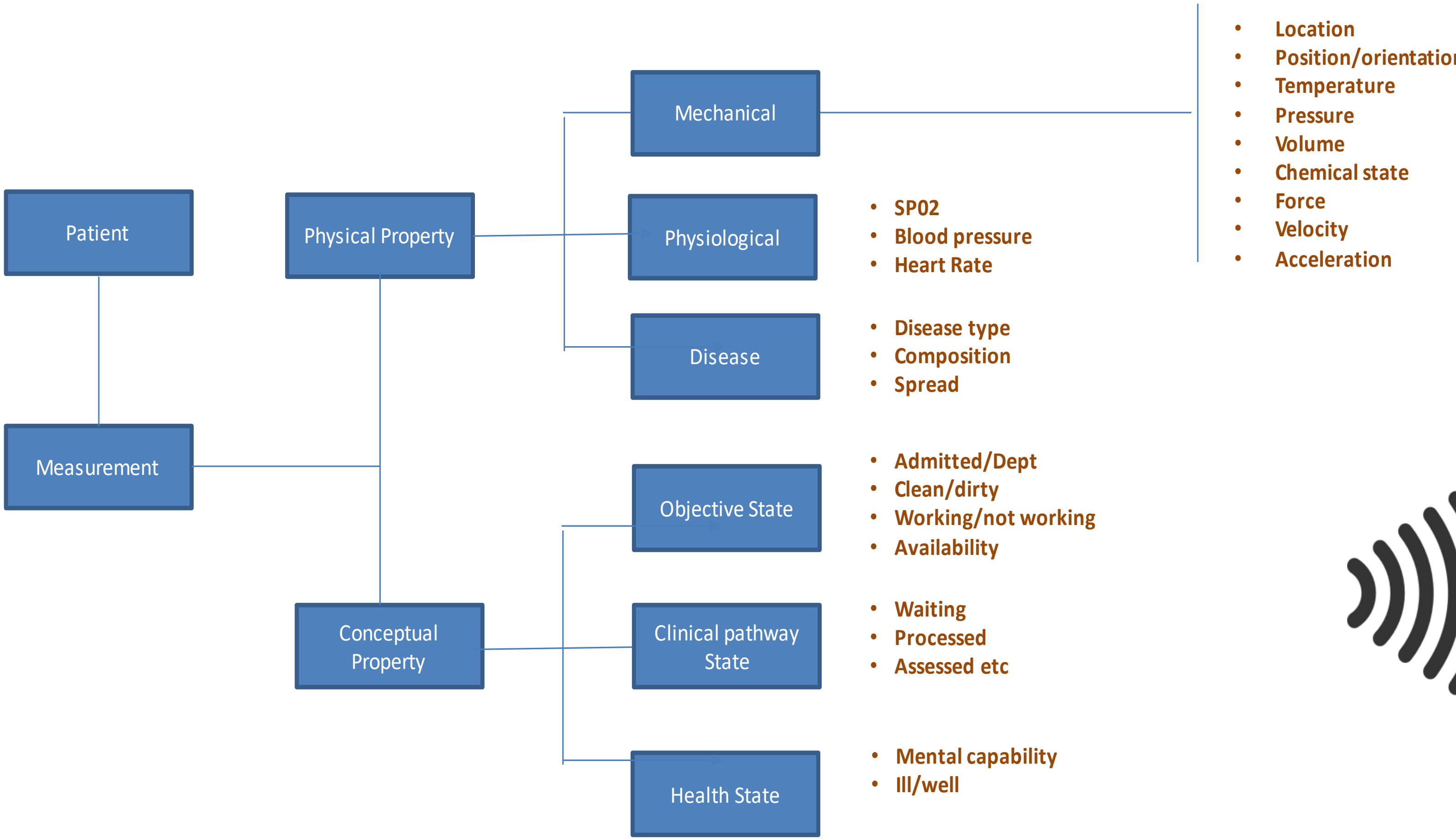
- Structured data input via humans

- Large input/output devices

- Human drivers

- Advisory for human control

What is IoT? Sensors



(Michell, 2014)

What is IoT? Architecture

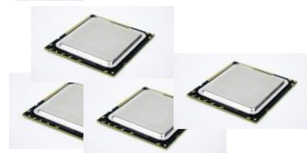
IoT Architecture

IoT devices work best as an integrated ecosystem of devices and programmed applications that provide sensing/actuation as part of an architected network working within a specific domain

(Michell & Olweny, 2017)

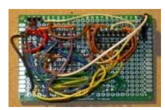
BUSINESS LAYER

Manages and uses the data for Human purposes eg bp of person x Is used to alert doctor y



APPLICATION LAYER

Processing of the IoT data eg making sense of blood pressure information in context



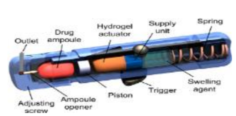
MIDDLEWARE LAYER

Connects and manages groups of devices eg bp monitors, Drug pumps etc as an IoT system

Local network

NETWORK LAYER

Transmits information from IoT devices to processing systems Eg bp monitor data transmission



PERCEPTION LAYER

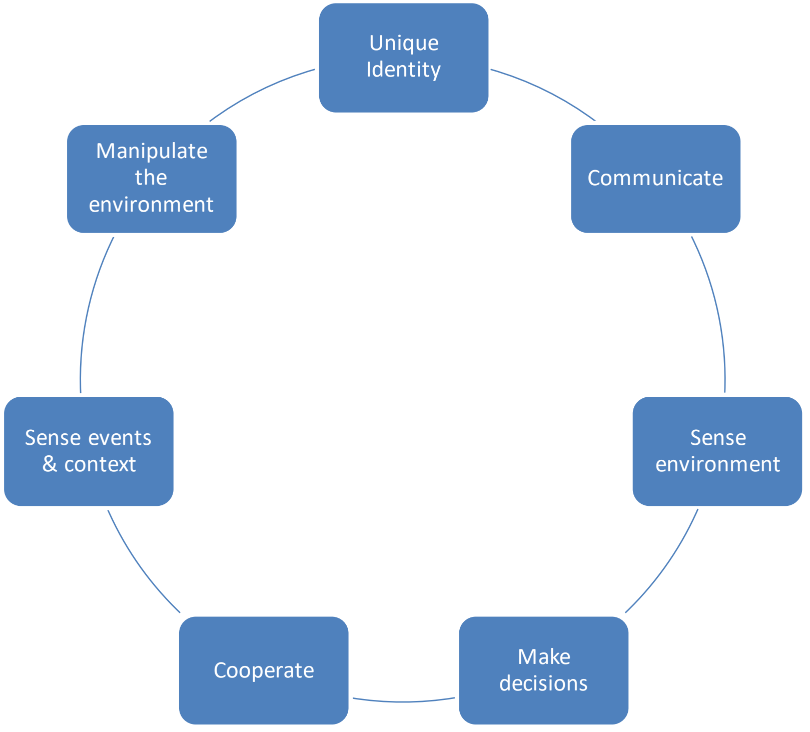
Device layer where the IOT sensor/device (eg bp monitor) data/actions are managed

What is IoT?

What we hope for: SMART IoT

Smart IoT depends on multiple sensor and information inputs combined with advanced rule based algorithms and knowledge bases to:

- ***sense the context on the environment***
- ***make sense of the information***
- ***make decisions***



(Michell IEEE Introduction to IoT , 2017)

Findings 1. Use of IoT: case examples, benefits and barriers

Findings 1. Benefits of IoT

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CONTROL AND MANAGEMENT

'Ability to present remote measurement data in real time'

'Enable rapid and safe patient discharge to community'

PATIENT SAFETY

'Access to data ensures patient safety'

'Reduce emergency admissions'

'Improve effectiveness and delivery of urgent and emergency care'

ACCURATELY MEASURE & COMMUNICATE SPECIFIC PATIENT CONDITION IN NEAR REAL TIME

NEW CARE OPPORTUNITIES

'Improve patient outcomes'

'Moving to new models of patient-centric care'

REDUCE EFFORT/COSTS

'Real time access and alerts when pre-defined conditions are not met eliminates waste'

'Reduce costs of COPD (treat 100 patients = £730k pa)

'To save time and lower costs in chemotherapy and also reduce the risk of infections'

Findings 1. Benefits of IoT

ACCURATE DATA 24x7

Quality and Value Sensor Proliferation

REMOTE CLINICIAN

Web linked sensors and resources

'The ability to measure and present conditions globally in an autonomous manner in real time'

'Remote sensing,

'The ability to continuously monitor the status and location of our devices and remotely manage them'

INDIVIDUAL PATIENT FOCUS

Sensor on patient, in patient, observing patient context

DATA FOR ANALYTICS AND BETTER DECISIONS

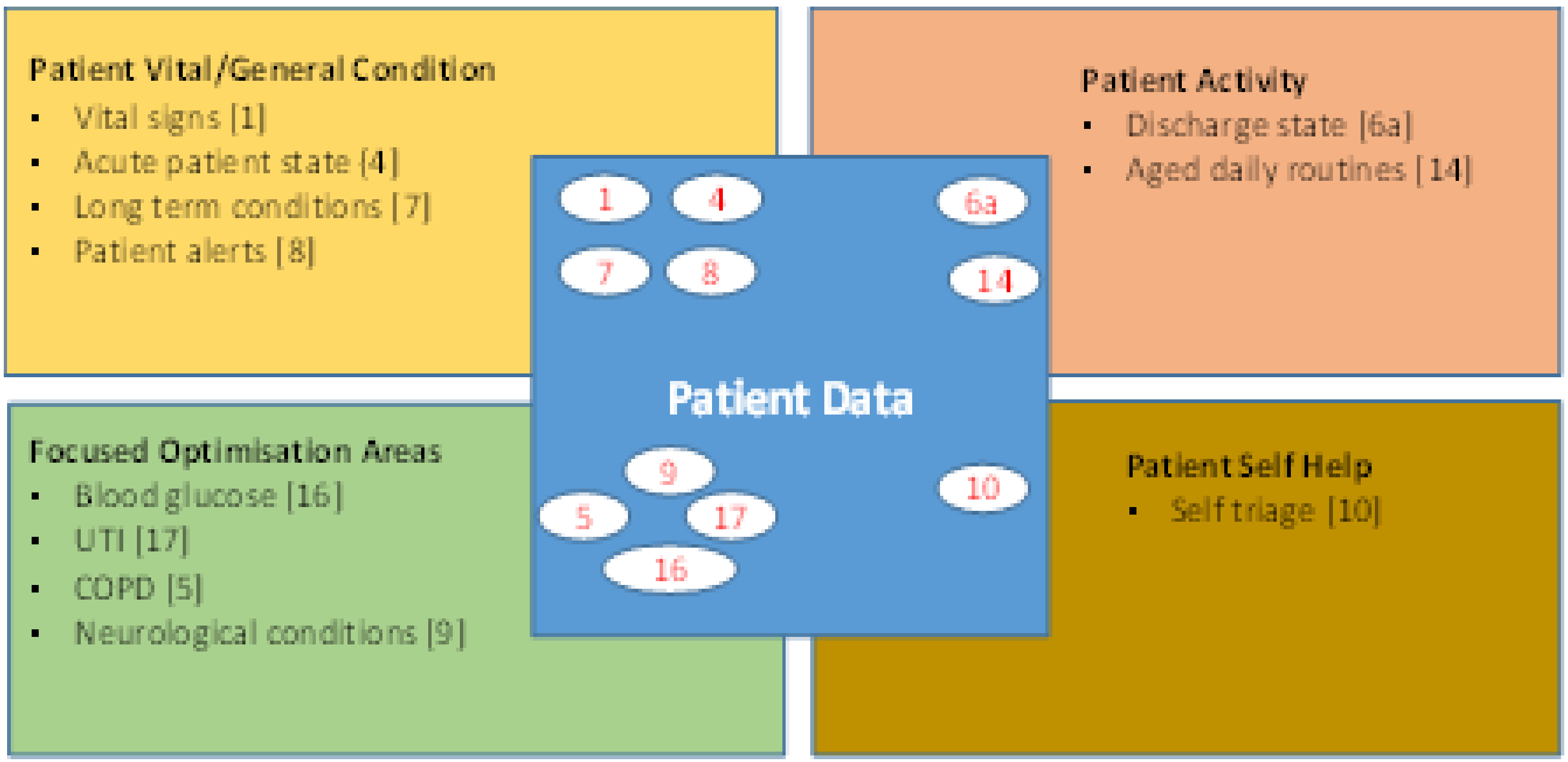
Collective Data Processing Web wide, Collaborative or local

'Massive patient empowerment, allows control with individual'

'data for analytics'

Findings 2.
IoT Process and Systems Challenges

Findings 2. Data Capture Range:



Findings 2. Data Focus Examples:

- Blood pressure
- Temperature
- Heart rate

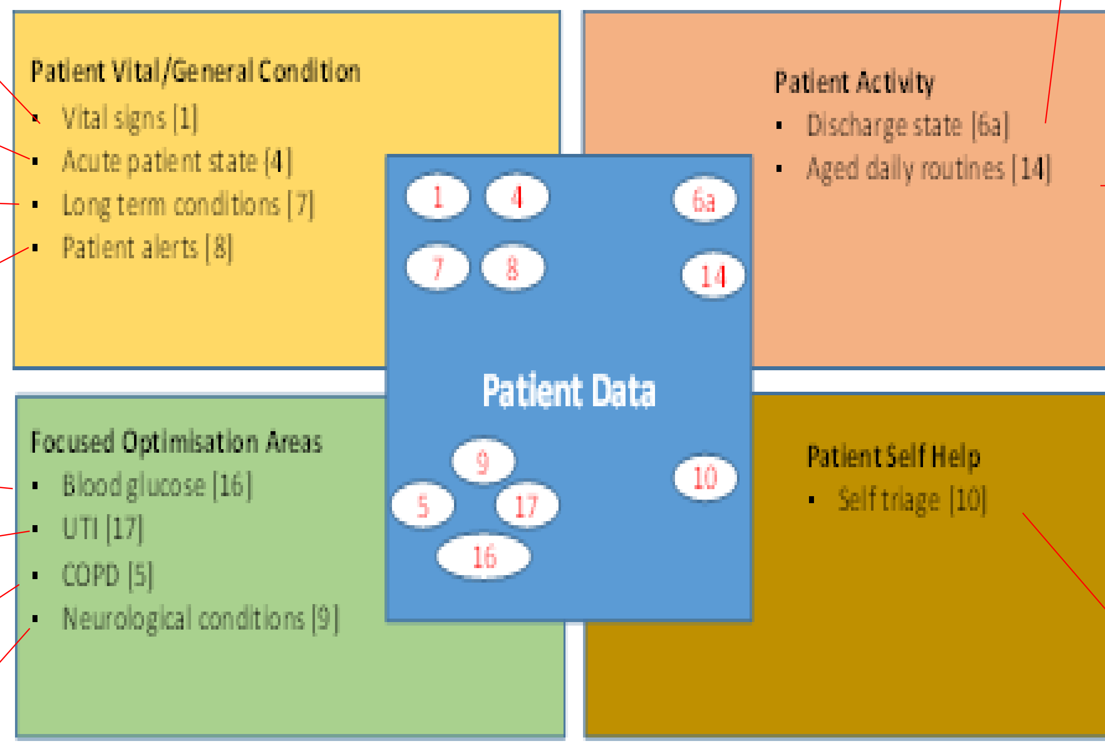
- Patient exceeds state measured by x

- Heart condition x: Respiration + heart rate + sweating vs condition

- Blood sugar
- Haemoglobin
- Timing alerts for medicines
- Location alert

Patient wristband ID returned

- Location in time period
- movement
- frequency



- Diabetic trends

- WC visits + temp vs threshold

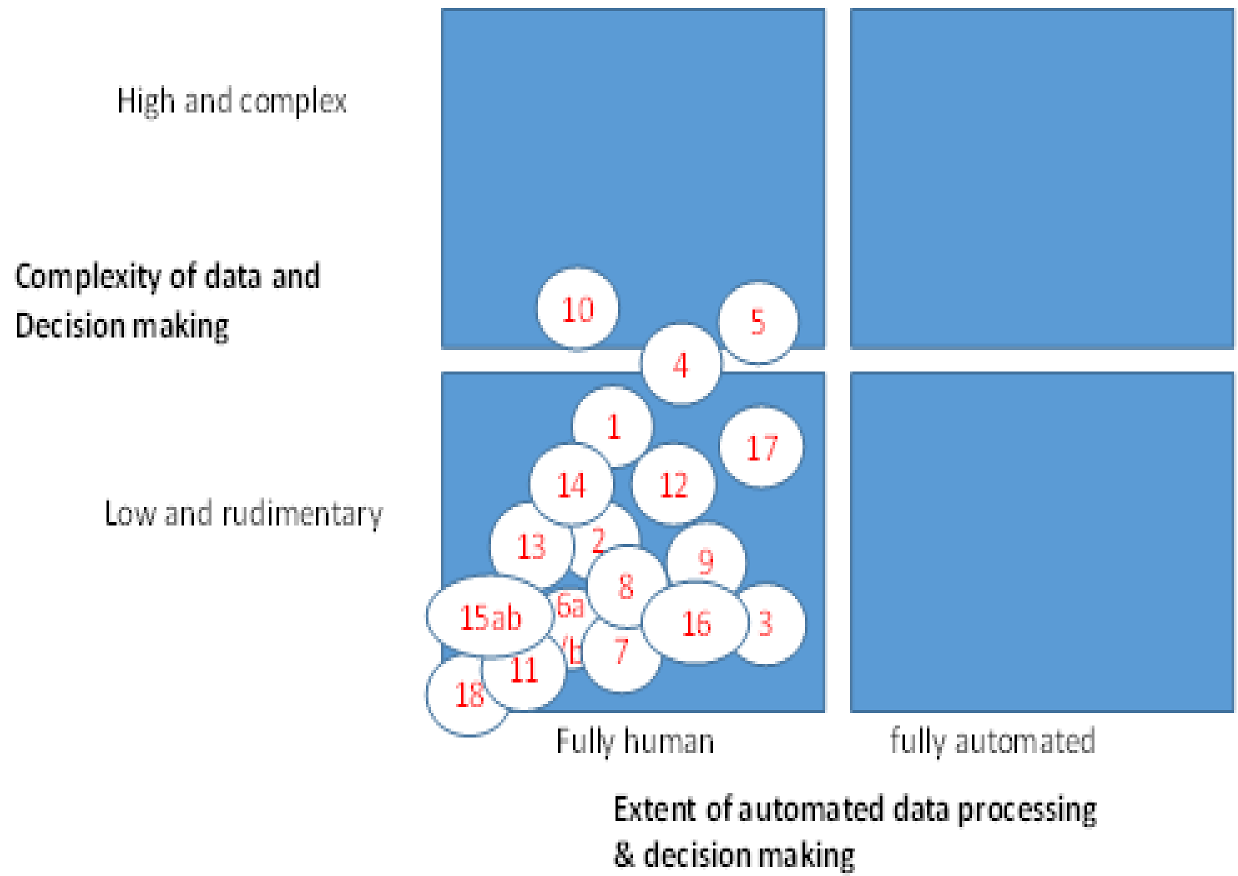
COPD:
- Respiratory rate
- Skin temperature
- SP02

- Patient Medical Symptoms vs Database rules

- muscle electrical activity (electromyography)

Findings 2. Decision Making:

- Mainly manual
- Data collection and delivery focus
- Routing to human decision maker
- Complexity mainly in volume, not options



Findings 3.
IoT Capabilities:

Findings 3. Capabilities:

- **Tracking**

IoT system ability to capture and process the location and/or state or other parameter of an object at a location over time

- **Monitoring**

IoT system ability to capture and process the change of a state or measurement over time

- **Control**

IoT system ability to ensure that the behaviour of a person or machine meets that desired, by taking corrective action

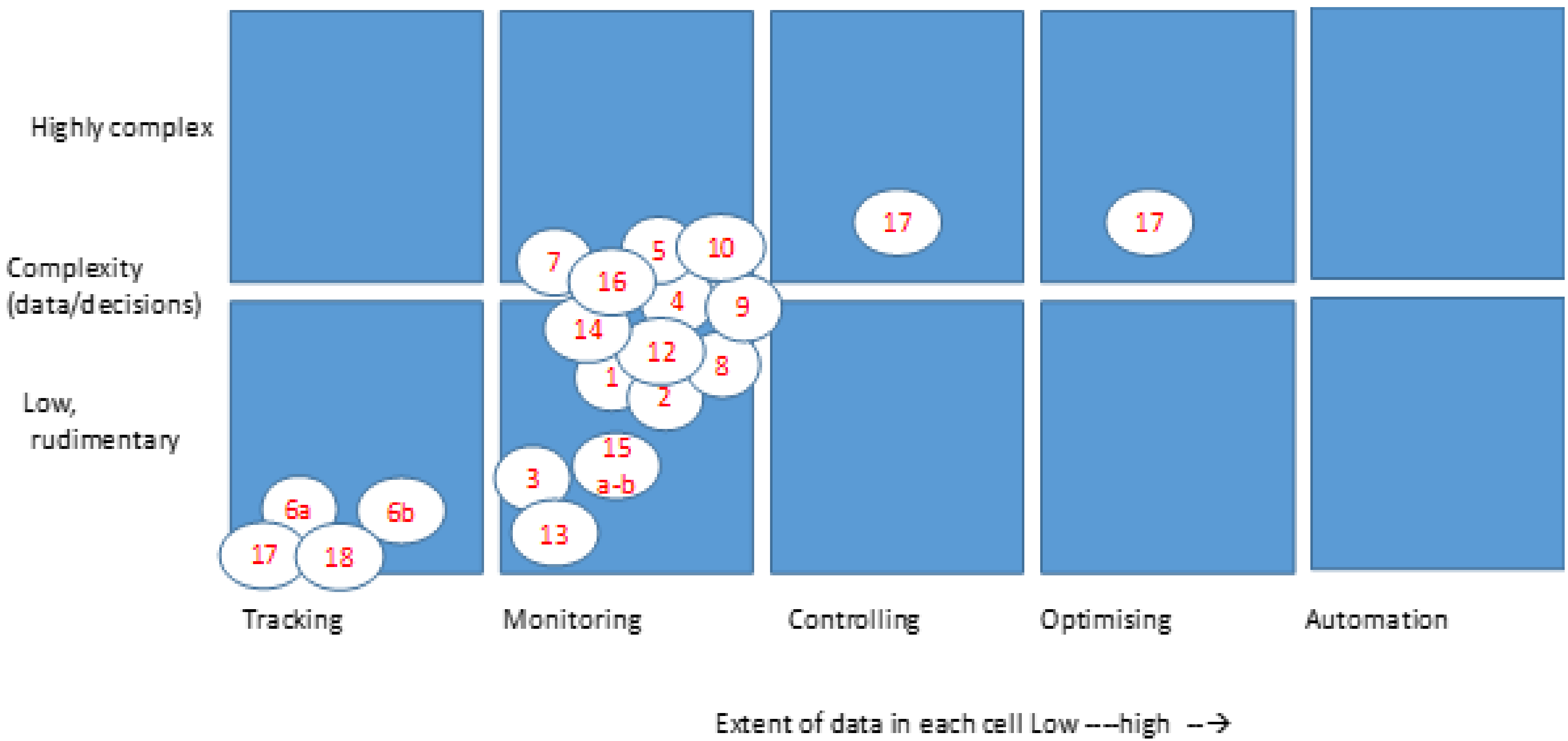
- **Optimisation**

the use of embedded rules and conditions to enable complex decisions to be made by the IoT system from IoT sensor/actuator information to improve the performance of a specific health activity

- **Automation**

Combination of monitoring, control and optimisation of data and information from IoT and other sources to enable an IoT system to make its own fully automatic decisions independently and act on the real world.

Findings 3. Data & Decision Complexity:



Findings 3. Performance Improvements:

Efficiency and Productivity Improvements

- *'it frees up staff to do more with less'*
- *fewer staff were needed to monitor remotely'*
- *'form filling and waiting time was reduced'*

Patient Centric Data Focus

- *'specific sensors for specific illnesses'*
- *'more specific illness conditions and measures from sensors enables greater focus and remediation of specific illnesses before they get worse'*

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Findings 3. Western isles Example:

NHS
Eileanan Siar
Western Isles

- **Due to the exceptionally challenging environment in the Outer Hebrides, the local NHS have embrac gy more than in some less demanding regions.**
  - Although Healthcare and Social Care are nominally owned by the NHS in Scotland, at the front-line there is still organisational separation.
  - In the Western Isles this means that the requirement to discharge patients to a safe, monitored home environment relies on cooperation between NHS and Social Care teams.
- **A demonstrator assisted living flat was originally fitted out with existing analogue equipment which had proven costly and difficult to integrate.**
  - Agreement was reached with the Social Care team and NHS to refit the demonstrator, (now complete) then a further 4 intermediate care flats with the Caburn solution (under way).
  - This is to be followed by an initial deployment to 18 patient's homes across Barra, Lewis and Harris.
- **Due to the design of our solution that uses stand-alone 3G/4G connectivity, widely available devices and is open-standards based, the costs are very low and the installation very simple, quick and non intrusive.**

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Michell V., 'Internet of Things, Digital Leadership in Healthcare' Masterclass London Leadership Academy, NHS England Woburn House, Tavistock Square, London, WC1H 9HQ
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Findings 3. Western isles Example:

NHS
Eileanan Siar
Western Isles

SOCIAL CARE

Providers develop only
Care focused technology

HEALTH

Providers develop only
Health focused technology

ASSISTED LIVING HOME

Telecare
Smart Home Hub
Peripheral Sensors *(Bluetooth)*:
- Fall sensors
- Geo-fence
- Doors
- Bed
- Movement
- Chair
- Carer Visits

Environment, Monitor & Control:
(Z-Wave, Zigbee, Wired)
- Heat
- Light
- Water
- CO
- Smoke
- Humidity
- Access & Security

Telehealth
Tablet Based
Peripheral Devices
(Proprietary / Bluetooth)
- BP Cuff
- Pulse Oximeter
- Spirometer
- Blood Glucose Monitor
- Weighing Scales...

Data Exported to:

Social Care Providers
- *Social Services, OT*
- *Private Contractor*
- *ARC*
- *Family / Nominated Carer*
- *Utilities*

Data Exported to:

Healthcare Providers
- *NHS Clinical Staff*
- *Private Contractor*

No Collaboration

No Coordination

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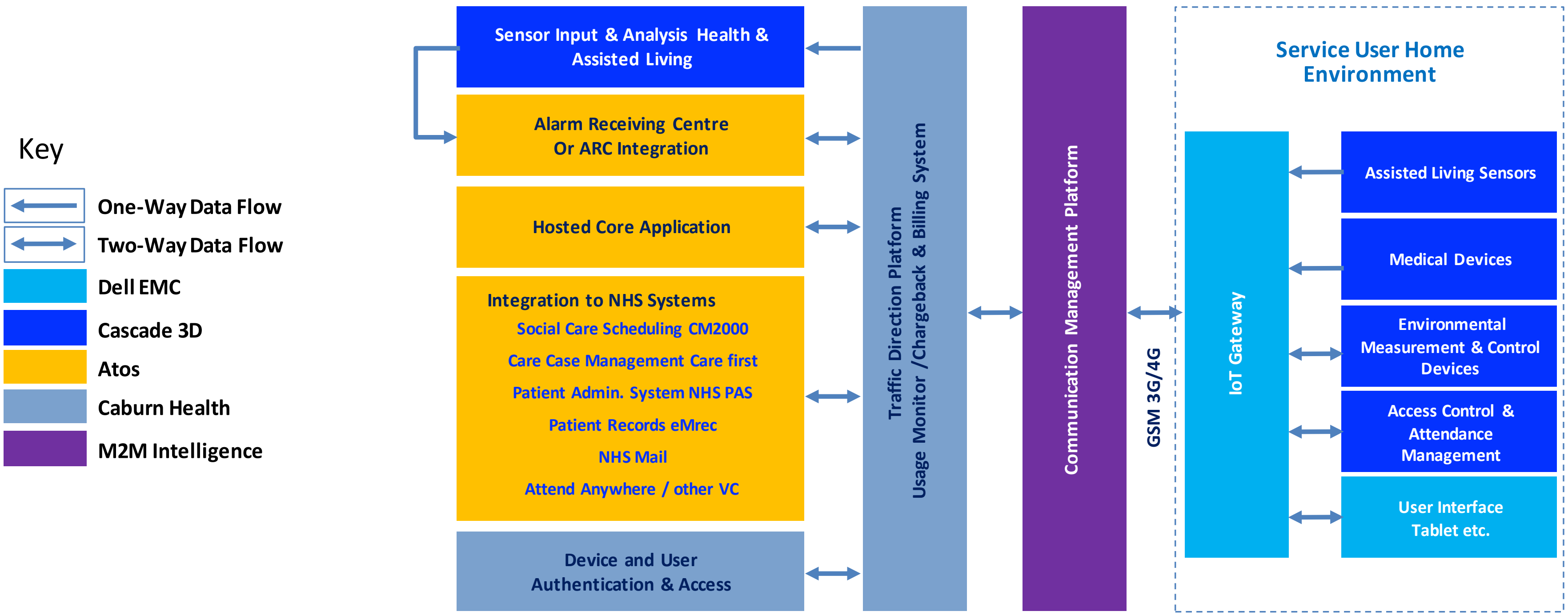
Dr V. Michell

Findings 3. Western isles Example:



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Findings 4. Support for IoT

Findings 4. Technical Challenges

Top to Bottom Engagement Required:

- *'work with other disciplines eg academics in design, frontend, backend and security experts re security applications.'*
- *'more engagement is needed in terms of use and support of the solutions was required for clinicians, medics and health staff' and 'working out how to launch a pilot'*

Systems Integrators are Vital!

- *;Hardware suppliers eg Dell, software and middleware suppliers and systems integrators'*
- *'integrators and those responsible for integration with NHS legacy systems, devices and data repositories, clinicians, care teams'*
- *'device integration, platform integration'*

Consultants Spread the Load:

- *'consultancy is needed or diagnostics (algorithms), identification of options and partner as we cannot do everything ourselves'.*

Findings 4.
Data/Decision Challenges

Sensors

- *'We need to know that sensors will be accurate and reliable'*
- *'Ensuring correct calibration is critical'*

IoT Culture

- *need for governance and safety procedures and an 'IoT culture'*

Security

- *'Security is an issue in terms of confidentiality of patient information'*
- *'security issues and privacy of data are critical'*

Apply IoT with care!

- *'some medical conditions may not be applicable for IoT due to risk issues, complexity and or potential for false positives/negatives'*
- *'whilst IoT can really help in primary and secondary care, not everything is suitable for IoT'.*

Findings 4.
Platform Challenges

Lack of Platform Standards

- *'lack of open standards' for IoT platforms, information etc. acceptance of IoT by users'*
- *'Need an open platform for data – trying to promote since 2012'*
- *'too many are just sticking data in isolated databases'*
- *'Microsoft is the only open platform – but pricing platforms is complex – difficult to understand'.*

Lack of Integration with Medical Systems/Users

- *'Interoperability with medical systems'*
- *'fear of using cutting edge/risky applications'*
- 'IoT *device integration issues'*

Lack of Common Communication Standards

- *'Communication standards and end of life of current technologies must be considered'*
- *'Communication standards and global consistency*
- *if there was one standard available globally the communication modules would be simpler and cheaper'*

Findings 4.
Non Technical Challenges a)

Business Case/Funding Requirements

- *‘clear statement of needs and clear use cases and examples’*
- *'Coming up with the right business model is a problem - how to fund the platform'*
- *how could an appropriate charging model be developed’*

Procurement Support Requirements

- *‘wider healthcare support to secure an approach to NHS commissioners is needed’*
- *‘There is a labyrinth of regulation and contacts to get past’*
- *We need to change commercial strategy to interact with the service’*
- *‘Procurement process is too rigid and not able to change….In future we will need agile and dynamic procurement change’*

IoT Drives Change of Working Patterns

- *‘All these ventures require culture change in work practices as many IoT solutions drive different working arrangements ‘*
- *‘need to work with public regarding use cases and how IoT might work in practice’*
- *‘concerns about privacy, and impacts of continuous monitoring’*

Findings 4.
Non Technical Challenges b)

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Data Quality and Cognition Overload

- *'There are issues managing, processing and analysing the continuous flow of data as we scale up'*
- *'we have to ask the right questions in an ocean of possible data'*
- *future IoT developments should include data filtering and exception driven reporting and opportunities to support the IoT community with professional services in this area',*

Risk and Litigation

- *'we need to address risk of litigation if an IoT device fails'*
- *'who is responsible for problems – the clinician, IoT device supplier, systems integrator etc?'*

Cultural/Education Issues: Understanding IoT

- *'Scepticism of new devices 'they will never work'*
- *'often culture and people change aspects are not addressed in IT changes – eg EPR –was expected to reduce paper notes, but clinicians are still writing paper notes as they have not altered their traditional culture practices'.*
- *The mismatch between costs managed in one NHS department and benefits seen by a separate NHS department reduces incentive to purchase from separate departments'.*
- *'The clinician attitude (to IoT) is not managed (needs to change). Part is fear of losing control and lack of understanding (of IoT).*
- *'There is not enough information on who it is for (IoT) and how it's used'.*

Findings 5. Future IoT

Findings 5. Future IoT

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Lifestyle Medicine

- '*use of IOT in lifestyle health monitoring and patient education to reduce demand and cost of care*'
- '*psychiatry / mood*'.

Chronic Conditions

- '*Falls, chronic illnesses*'

Emergency Medicine

- '*More devices connecting vital signs*' to more novel '*wound care*'

Resourcing/Logistics

- *they are often not done effectively as resources are focused on direct delivery of care to patients rather than efficient record-keeping and back-office management and easily lend-themselves to automation"*

'Products'

- *the ability to effectively and consistently measure true/directly effectiveness of "products" drugs, diet, surgeries, treatments, rehabilitation etc available in the health industry*

Conclusions

Conclusions: IoT Installations

- Mainly monitoring & tracking capabilities
- Basic data and decision making used so far
- Little fully automated control - human in the loop
- Point solutions focused on specific illnesses/metrics
- Simple IoT 'systems' – few sensors, metrics and variables
- 'Smart' IoT, optimisation/automation is way off
- IoT limitations resolution required
- IoT is not suitable for all conditions

Conclusions: Gaps

- Lack of platform, communications and integration standards
- Risk of cognitive overload unless filters/automation of decisions
- Understanding of sensor accuracy and limitations is needed
- A standard IoT hub/operating system is needed
- Better integration with existing health systems is vital
- Health IoT needs a new business case/innovation funding solutions

Conclusions: Opportunities

- IoT solutions can save money, time and lives
- IoT solutions require multidisciplinary teamwork
- Experts at all levels required, particularly solution level
- Consultants required to fill the gaps/integrate providers
- IoT education is vital – particularly for users/those impacted
- Health approach needs to change to embrace IoT/technology
- Culture change required for IoT fulfilment
- IoT opportunities are pervasive and offer capability sea change

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Appendix