Designing a Healthcare Cognology: Healthcare Autonomous Agents for the Internet of Things

Background Paper for a Proposal to the Technology Strategy Board

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The Internet of Things and Healthcare

Healthcare systems have been slowly evolving toward a model of care delivery that seeks to leave behind the traditional medical model, based on fighting diseases – sometimes called the *lesion-theory of medicine* – and which has driven health care thinking since the 1800s.

The *health ecology model* conceives healthcare as about helping people live their lives well, seeing ill-health and disease within an ecology comprising choices they make, the context in which they lead their lives and importantly, on the central role of the individual within that ecology to decide how to organise healthcare to help them lead this life. In that respect, the ecological model is more in tune with the real, complex, nature of the world with the various parts working together more in a self-organising manner to achieve desired results.

Self-care has been the best response to the realisation of this complexity and we have examples such as the expert patient, patient activation, patient reported outcome measurement, disease or care management programmes, managed care, and health promotion and lifestyle programmes.

At present, many health systems and policymakers are focused on chronic ill-health or long-term conditions, which entail continuing healthcare requirements perhaps over the lifetime of individuals and requiring varying degrees of support. Many long-term conditions arise from lifestyle choices in part and that explains why there has been a focus on engaging the patient in the care process, to ensure that they are inclined to make the necessary choices to avoid further exacerbations in their conditions, or indeed to avoid these conditions in the first place.

The California Healthcare Foundation, this year, stated [www.chcf.org/topics/health-it]: 'information technology is still fairly new and untested in health care, making experimentation, analysis and evaluation critically important'.

We know technology helps to enable not just efficiencies and effectiveness, but also the greater personalisation of services – consumerisation. The impact of technology, therefore, includes, but is not limited to:

- breaking down (or disintermediating) processes to remove steps that do not add value to the end-user experience, or which have no useful role to play, despite being seen as current good practice by professionals; this can create novel service integration;
- shifting skills toward customer-facing staff (e.g. consider how different banking has become)
- widening public access to hitherto restricted health information to patients, including information on clinical performance. In some cases, this has been mandated (such as public information on hospital performance) or has evolved in response to customer interest (such as health websites providing information and advice on health conditions);

- enabling organisations to create new ways to engage with the consumer or end-user more effectively in improving products and services than the traditional customer/supplier relationship.

A particular impact is relevant in healthcare, namely

- moving knowledge across the boundaries of regulated professions (e.g. to imaging technologists from radiologists, from doctors to nurses).

Healthcare is highly regulated and the application and use of professional knowledge legally regulated. The effect of this has been to compartmentalise knowledge and skills within a broad hierarchy, with the doctor at the top, in effect, as the default health professional who supervises and validates the application of knowledge and skills by other professions. This, of course, is changing, partly as a response to the sheer complexity of healthcare and the levels of knowledge and skill involved, but also through new ways of working, in teams, and across organisational boundaries, with skilled nursing care facilities, polyclinics, etc. The patient, though, has not been an immediate beneficiary of this.

As knowledge has migrated away from people into devices, we have seen the invention of patient-use devices which in the past have required sophisticated testing and professional knowledge; an obvious example is the pregnancy testing kit, and many mice and rabbits are no doubt relieved at its invention.

The impact of embedding knowledge in devices in healthcare, and thereby the potential impact on the internet of things within hospitals and for patients unbundles knowledge cartels and redistributes it. This diagram illustrates the three key directions: (after Lehoux):

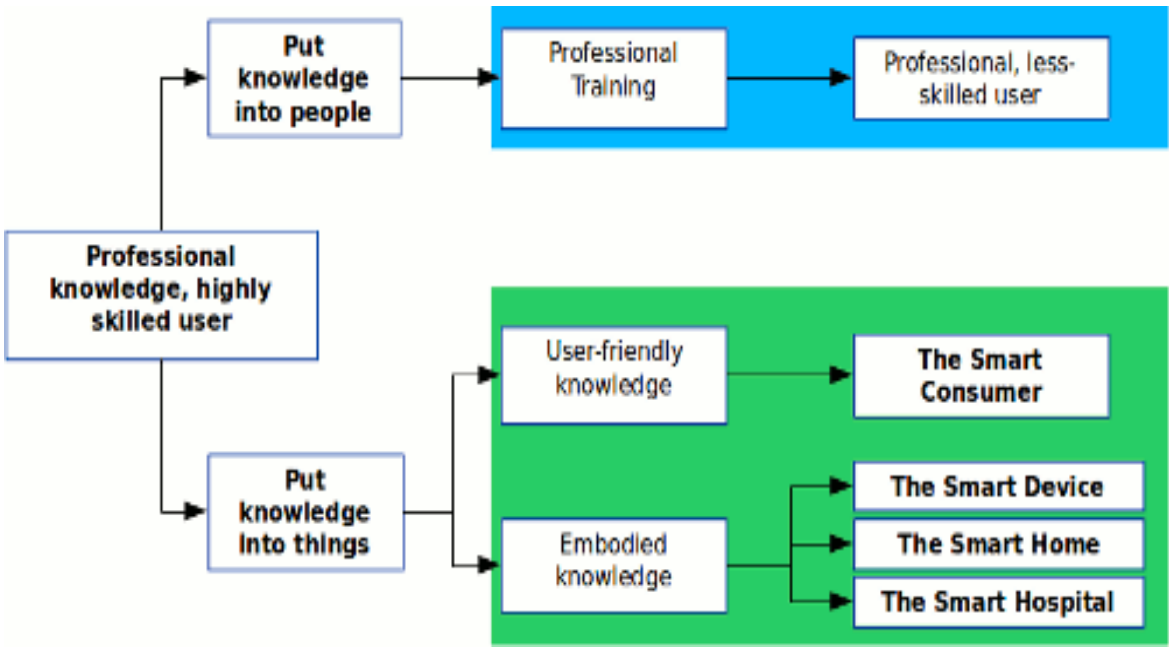

Illustration 1: Shifting Knowledge and Skills

Source: modified after Lehoux

Putting knowledge into people means training them, and it can either shift knowledge to other professionals, such as is found in interventional radiotherapy (imaged-guided surgery), whereby surgeons interpret imaging results in theatre, replacing a separate radiologist. Knowledge can also be given to patients, by simply enabling them to have access to more knowledge and insight; this has been a key impact of the internet and which has raised many issues around the quality of health information on the internet. Knowledge can be put into devices, which can be used by patients and consumers, and where the device does what a health professional used to do. Finally, technology can enable knowledge to be put into 'systems' to generally interact with people, such as in the home, or hospital, for instance; it is the embodiment of smart devices within systems that particular benefits are seen as emerging.

In the respect of these considerations, we see the Internet of Things as helping significantly to achieve greater personalisation of service delivery, and this proposal addresses specifically the opportunities of the Smart Hospital and the Smart Home to support the Smart Consumer.

Why do we want this greater personalisation within a healthcare context? Because evidence demonstrates that customising services is effective -- patient outcomes are improved, patient experience is positive, and the provider gets better value for money. An example is the work being led by the Patient Reported Outcomes Measurement Group at Oxford University. [http://phi.uhce.ox.ac.uk/home.php]

Where this proposal differs from just another IT or e-health project is that we see personalisation being enabled through autonomous agents acting on behalf of the patient and thereby enabling the patient/consumer to drive their preferences and choices, rather than these emerging through professional delegation.

- A vast array of device technologies are used in healthcare, particularly in hospitals, probably the most complex organisations in our society. A known priority within healthcare is to integrate the vast sea of information produced, whether conclusions by clinicians, activities of patients, the output of devices, or underlying information such as financial performance, inventory, or quality. Progress is slow and mixed.
- E-health has largely failed to get substantial traction, either as a mode of service delivery, or commercially, despite being seen as having considerable potential, by enabling better linkages between operational parts of the healthcare system with the patient.
- There are many approaches to integrating information across this information value chain, with the electronic health record (EHR) seen at present as key from a clinical perspective, along with opportunities real-time monitoring of patients outside hospital through sensors, or interacting with patients through video teleconferencing. Most countries are grappling with how to enable patient access to the EHR, with concerns around identity and security being central, but this debate is being carried by the healthcare providers that still sees the EHR as belonging to them, and not something literally owned by the patient.
- Electronic prescribing, is seen as reducing medical errors, and better correlating patient data with rational prescribing, but the benefits to patients

are limited, in the main, to electronic delivery of the prescription to the pharmacy of their choosing, but this is a choice that is already theirs.
- Other areas, such as care management programmes using remote monitoring, SMS alerts, etc. but little of this is really new, as they are mainly automating existing activities, and facilitating better communication.

Our proposal starts from a different place.

We are mindful of underlying clinical requirements in the hospital, such as linking the dispensing of a medicine to a patient (informed through clinical decision-support prescribing system and documented accordingly) with bed-side capabilities to ensure the right patient gets the right medicine, and linking that in turn back to batch control and inventory control, budgeting and procurement, not to mention links to quality assurance, audit and utilisation review. And should the patient react badly to the medicine, batch control can help identify any problems with the medicine itself, such as expiration date, or even whether it is counterfeit. How are we to design a system that seamlessly makes all this work?

But we are starting with the relationship between the patient and the hospital in this proposal, a relationship, built on trust, and on service delivery, communication, treatment, and information. Illustratively, a wireless world of healthcare is possible, which respects this. [Wireless World Research Forum]

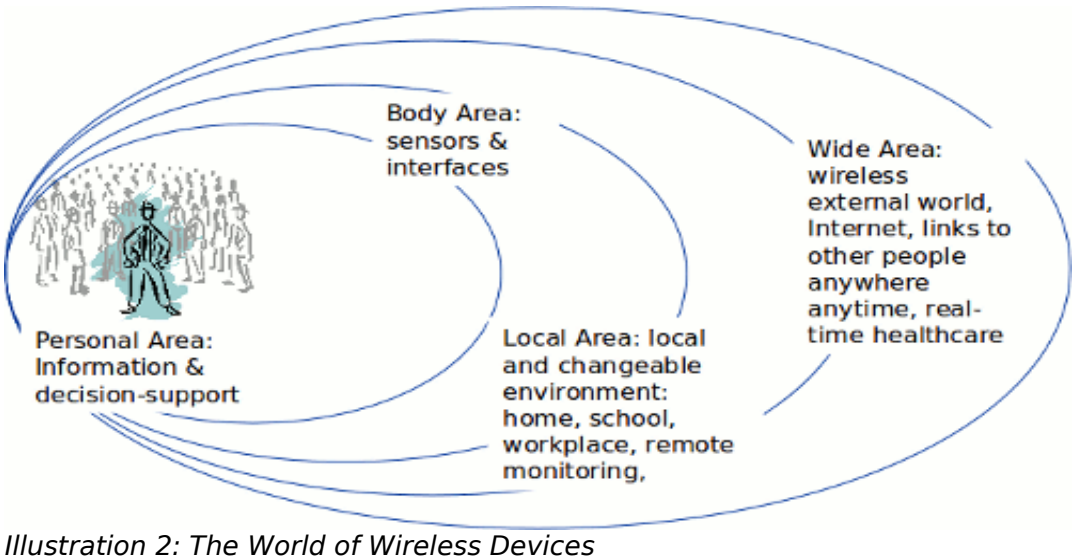

Illustration 2: The World of Wireless Devices

Source: Wireless World Research Forum

Autonomous agents and the next stage of evolution of the Internet of Things

"Cognology" is a term coined by Tremblay to describe the evolution toward technologies with embedded intelligence. The TSB recognises there is no one clear definition of the Internet of Things. We have adopted the operational definition of how the internet of things should work in healthcare from Kosmatos et al 2011:

"... a loosely coupled, decentralized system of smart objects—that is, autonomous physical/digital objects augmented with sensing, processing, acting and network capabilities."

The implication of operationalising devices within a cognology and fitting this definition is to alter our current notion of the internet of things from a cognitive perspective. That is to say, the 'thing-ness' of devices that we perceive to be the interesting development evolves as autonomous agents give functional purpose to these things. This in effect means moving from a view of the internet of things defined as bundles of technological capabilities, and more as a 'distributed cognitive system' [Tremblay 2005] defined in its ability to evolve and transform itself in response to changing circumstances, rather than a strict functional hierarchy.

Conversion of the internet of hospital things into the internet of self-care (or what might be thought of as 'my things'), through autonomous agents bridges the gap between the hospital setting and the personal context (home, school, work, play), in effect by having the autonomous agents 'repurpose' the device.

The 'wireless' model illustrated early is apt here to the extent that the individual is the focus of the cognological capabilities provided by smart device technologies. This achieves the additional benefit of shifting the focus away from technologies that can deliver this or that service, to the use of the information and its manipulation to achieve various goals.

We also think it is important to adopt Simon's *technological agnosticism,* to ensure we are focused on results, rather than 'things' as such.

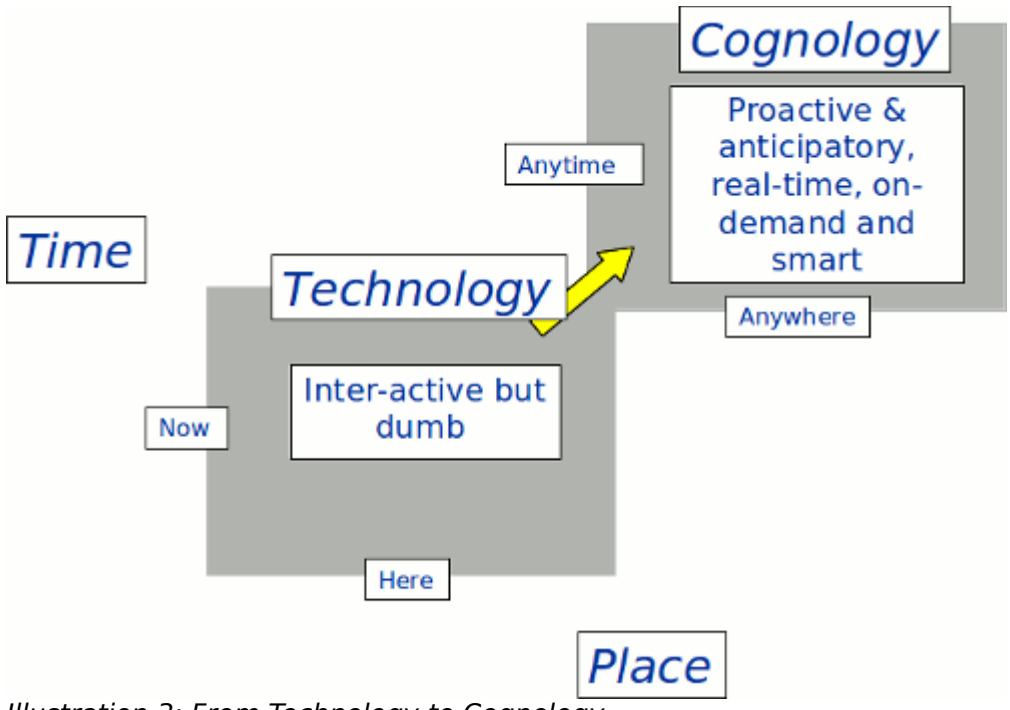

Illustration 3: From Technology to Cognology

Source: Tremblay

We think of this shift from technology to cognology as achieved in part through advances such as the potential of the internet of things, with the embedding of functional intelligence in devices transforming them from physical things into cognitive things.

In this respect, the internet of things is a misnomer.

What have we already done in this area?

The participants have experience as follows:

Living Health

Living Health was launched in 2001, being the world's first interactive digital television health channel, which tested out the potential of bringing health services into the home through the television. An information and transactional service, it was the first publicly accessible interactive service, in the world, that enabled users to book a doctor's appointment, access and search a reliable and validated medicines and health information repository, and have an "In-Vision", a one-to-one, engagement with an NHS Direct nurse. *Living Health* won a number of international media and service awards, with independent evaluators concluding '*Living Health* fulfilled a direct and immediate consumer need for such a service, as well as demonstrating the opportunity for direct savings to primary healthcare providers'.

Drawing 1: Source: Living Health

In June 2002, Tessa Jowell, then Secretary of State at the Department of Culture, Media and Sport, stated in a speech to Social Market Foundation:

"I was recently shown the NHS experiment being run in Birmingham. 30,000 households can access a wide range of medical services, some personalised to them, through their TV set. It's informative, it's accessible, it's interactive. It is both broadcasting and narrow-casting. It is a convergence of technology, but also a convergence of sectors – public and private, communications and health".

Although significantly disruptive of existing NHS approaches, it became the core of NHS Direct Digital.

Technology in the Community

The second area involved identifying the role of embedded intelligence in the use of technologies to shift healthcare from hospitals into the community; the model identified how to enable 'smart' technologies for the 'smart consumer' the 'smart home' and the 'smart device', including: smart medicines, electronic prescribing, self-testing, health information and electronic health records, smart cards, and virtual

clinics. A Roadmap was developed for the period 2010 to 2018 to facilitate incorporation of evolving technologies. (Tremblay, Walshe 2008).

Proposed Approach

The internet of *hospital* things

Healthcare technologies should have certain degrees of freedom:

- **of geography:** in terms of home, hospital/clinic, ambulance, workplace, etc. to support location-independent care;
- **of intelligence:** embedded 'intelligence' of one sort or another proving a constellation of capabilities, but perhaps most importantly, a predictive and anticipatory capability;
- **of engagement:** seeking out and exchanging at various levels and in various forms with people (doctors, nurses, patients, carers, etc.), with processes (admission, discharge, alerting, quality monitoring, etc.) and with other objects (blood gas monitor, diabetic monitor, cardiac monitor).

We see the Internet of Things as a different approach, which, when coupled to the use of autonomous agents, offers substantial opportunities to recast clinical processes so making the patient central to healthcare. This consumerist approach will render dated many e-health initiatives for example, as well as the current approach to the EHR.

Development of autonomous agents

This proposal takes a consumerist, or patient-centred, approach and focuses on the design of an 'intelligent autonomous agent', the *Personal Health Agent* [PHA] to be used by individuals as they choose.

On the hospital side, we see the development of a '*smartEHR agent*' to sit 'atop' the existing EHR as the main point of contact with the PHA.

The PHA pulls services, information and communications from various sources, such as from the hospital, from the SmartEHR (as gateway the EHR), and pushing the individual's health preferences and goals toward health providers, for example.

The SmartEHR is an intelligent integration application linking up the internet of hospital things on the one hand, and pushing information, test results, appointments, and services to the patient, interacting with the PHA, as well as pulling information from the patient and responding to patient priorities.

The development of these dual autonomous agents is a substantial advance on current thinking on the role of agents in healthcare. [Autonomous Agents and Multi-Agent Systems for Healthcare]

We are mindful of research that shows that device design in healthcare is essentially driven by the interests and needs of clinicians, rather than patients [Lehoux] because developers and designers have seen clinicians as the end-user since they specify the

use of these technologies for patients.

However, where patients, rather than clinicians, are seen as end-users, novel solutions to pressing concerns have emerged, such as Novo Nordisk's *EpiPen* (insulin autoinjector), which was explicitly designed through a consumerist approach. [www.epipen.com], or the *DIDGET* meter from Bayer Diabetes Care, which links to the Nintendo DS consoles and is designed to help children with diabetes manage their condition by rewarding them for consistent testing and meeting personalised glucose target ranges.

Illustration 4: Source: Bayer

While much research, study and application development is taking place in healthcare, within e-health for instance, and with various 'apps' for smartphones, we see our proposal as charting connectivity, purpose, functionality, and design of both devices and healthcare systems, and conducted in a realistic consumer-defined setting.

Development of a framework to test autonomous agents

To advance the work, itself, and from our experience, we propose to develop a framework within which to test the role of the autonomous agent to bridge the gap between the hospital and the consumer/patient.

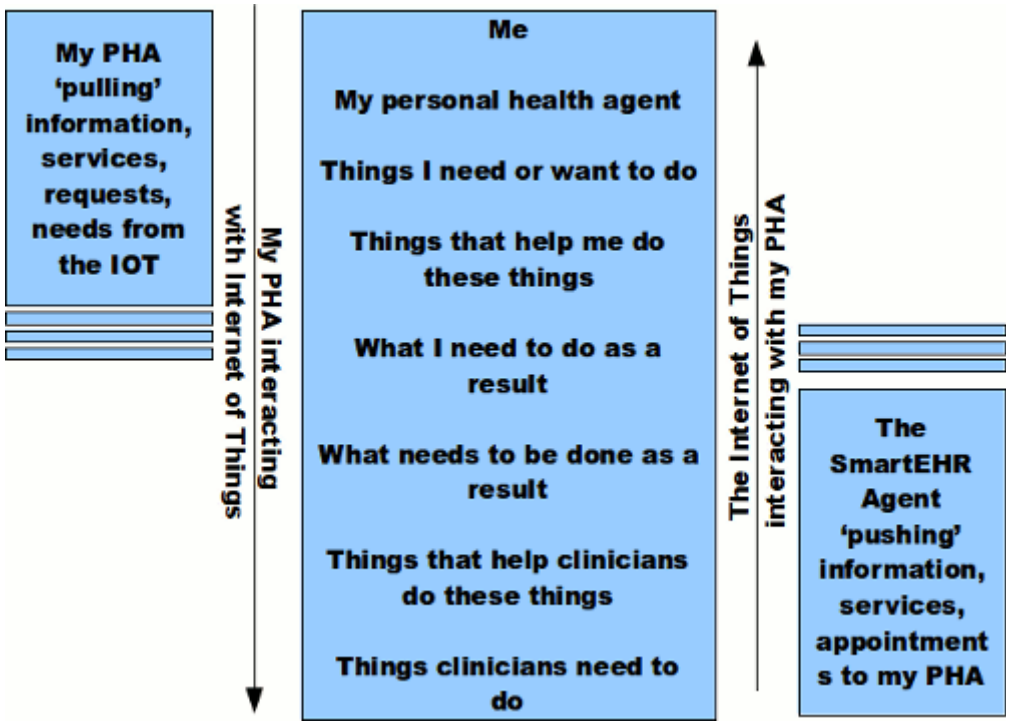

Illustration 5: Schematic of the Internet of Things, illustrating high-level purpose of the twin agents

Source: Tremblay

The next chart is a more detailed illustration of the hospital structure taking account of the key elements, keeping in mind that a key feature of the behaviour of the autonomous agents on the internet of hospital things will be to turn them into the internet of home/school/work/play things, within the distributed cognitive system to be created.

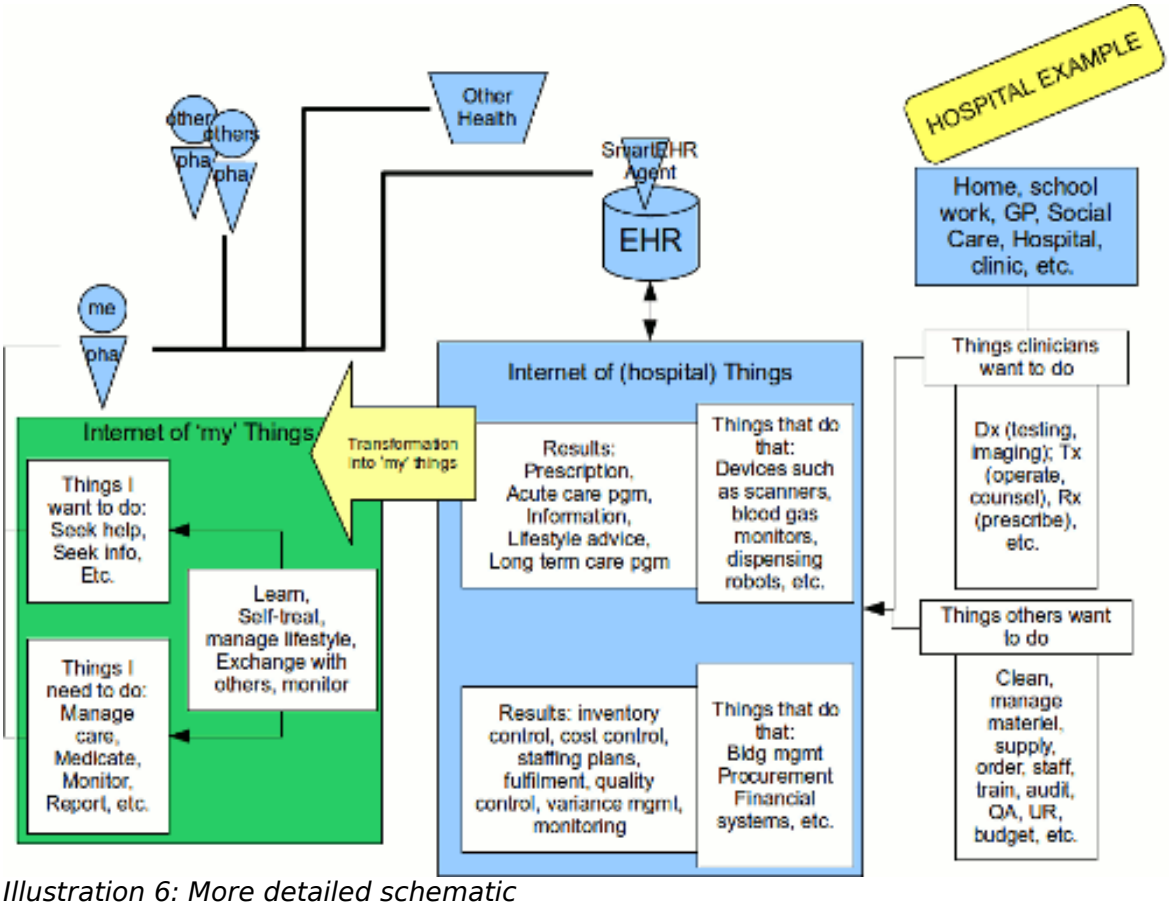

Illustration 6: More detailed schematic

Source: Tremblay

The objective of the project, therefore, is to construct a logical framework for the design and development of these autonomous agents, and test them out with a selection of candidate clinical device technologies, which can be re-purposed by the agents for use by people in their own world, what might thought of the internet of 'my' things.

Examples where we could test this out in the first instance include:

- mental health
- cardiology
- imaging
- medicines use

The project will develop more fully the opportunities to engage device manufacturers to enable their devices to work with our agents, and explore patient preferences for the underlying use that they would put the agents to.

Our experience with *Living Health* involved structured discussions with consumers and end-users to determine the design and 'user friendliness' of the television channel, and at the time was produced the most comprehensive understanding of how people looked for and used new media for health purposes. We see this presenting similar

requirements and opportunities to recast current approaches.

Areas to be agreed in due course with TSB include the commercial exploitation of the intellectual property created.

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