Computação Móvel e Ubíqua

Instituto de Informática - UFG

Prof. Fábio M. Costa — 2023/1

Conceitos fundamentais

Smart Spaces e Descoberta de Recursos

Definição

Smart Spaces

“Ambientes computacionais e sensoriais altamente integrados que `raciocinam´ efetivamente sobre o contexto do espaço (físico e do usuário) para atuar transparentemente com base nos desejos dos usuários” [Lupiana et al. 2009]

Original:

“A highly integrated computing and sensory environment that effectively reasons about the physical and user context of the space to transparently act on human desires”

Definição

Smart environments

- "Um ambiente capaz de adquirir e aplicar conhecimento sobre o ambiente e seus habitantes com o objetivo de melhorar a experiência dos habitantes no ambiente". [Cook & Das, 2007]

Original:

- *“We define a smart environment as one that is able to acquire and apply knowledge about the environment and its inhabitants in order to improve their experience in that environment.”*

Exemplos de smart spaces

(ou: ambientes que podem ser transformados em smart spaces)

- Residências
- Escritórios
- Salas de aula
- Prédios comerciais
- Parques
- Campus
- Cidades
- etc.

- Em geral: ambientes delimitados
  - Facilita o gerenciamento dos recursos no ambiente (dispositivos, usuários, serviços)
  - Facilita a definição de contexto
  - Aspectos administrativos
- Extensão: federação de ambientes inteligentes

Smart Spaces (ambientes inteligentes)

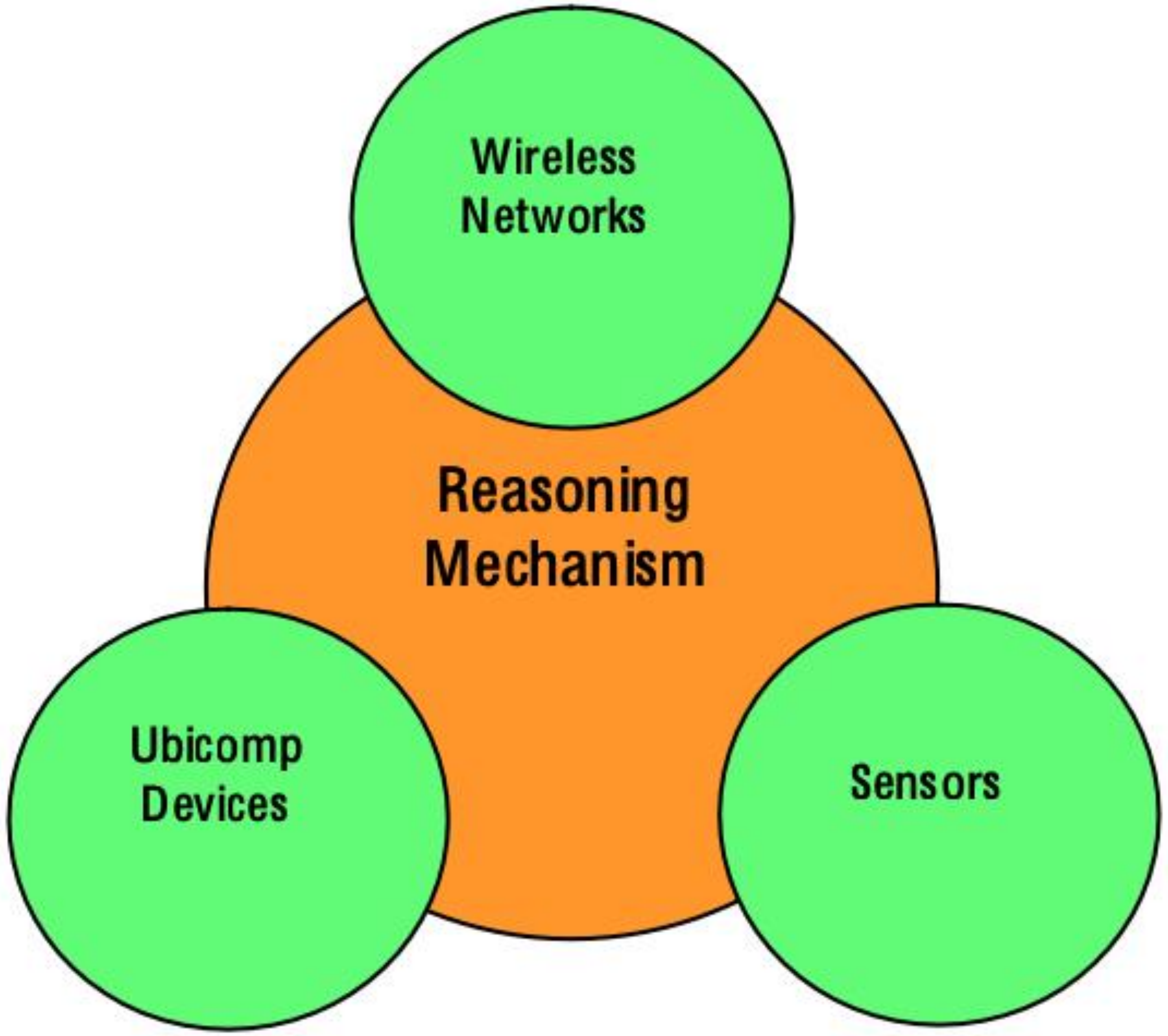
Um tema multidisciplinar, envolvendo diversas áreas

- Computação móvel e ubíqua
- Redes de sensores e IoT
- Inteligência artificial
- Robótica
- Computação multimídia
- Middleware
- Software baseado em agentes
- Interfaces de usuário

Elementos fundamentais de smart spaces

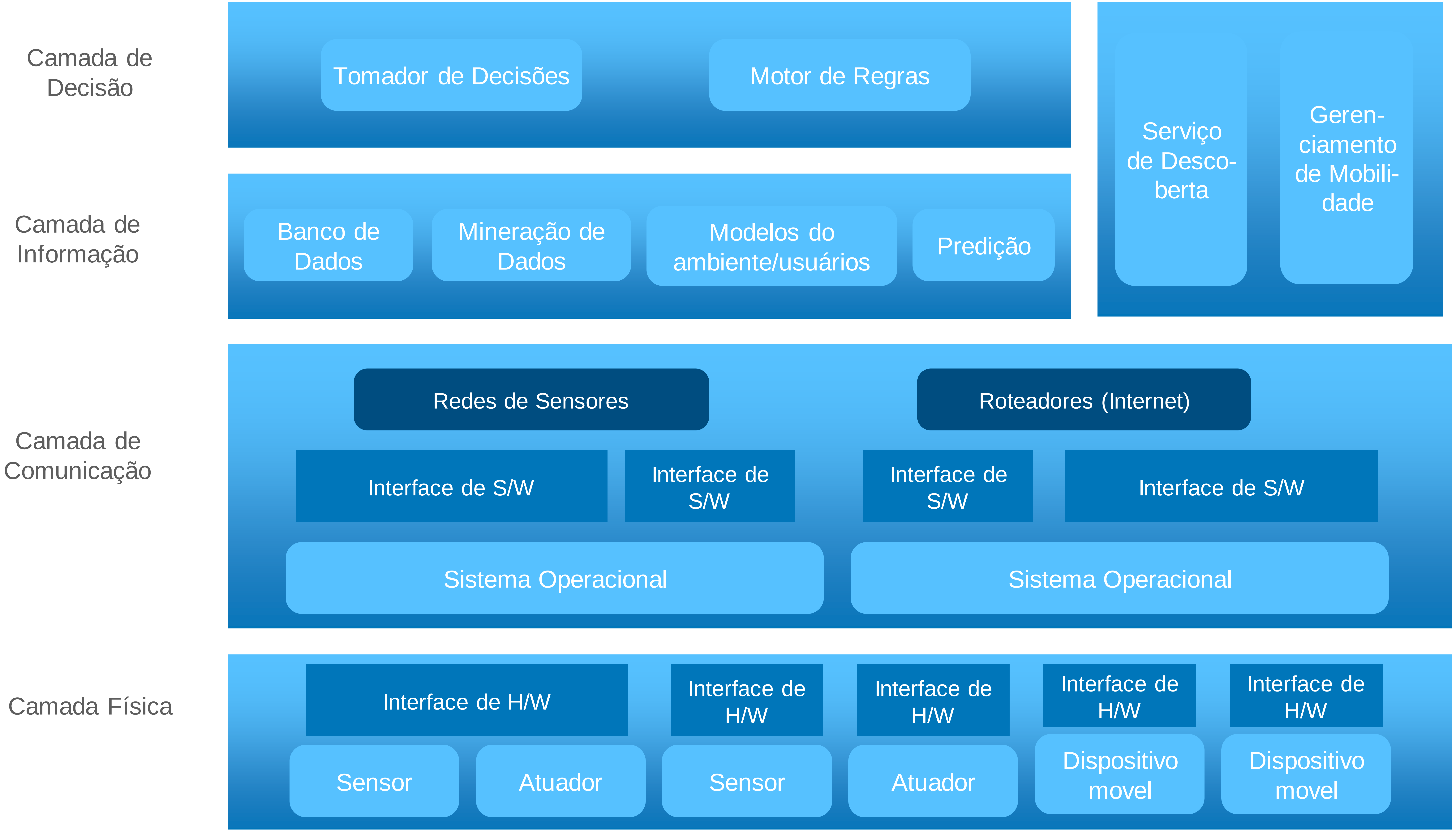
[Lupiana et al., 2009]

- Dispositivos ubíquos
- Sensores (e atuadores)
- Redes sem fio
- Mecanismos de “raciocínio” e decisão



Componentes de um ambiente inteligente

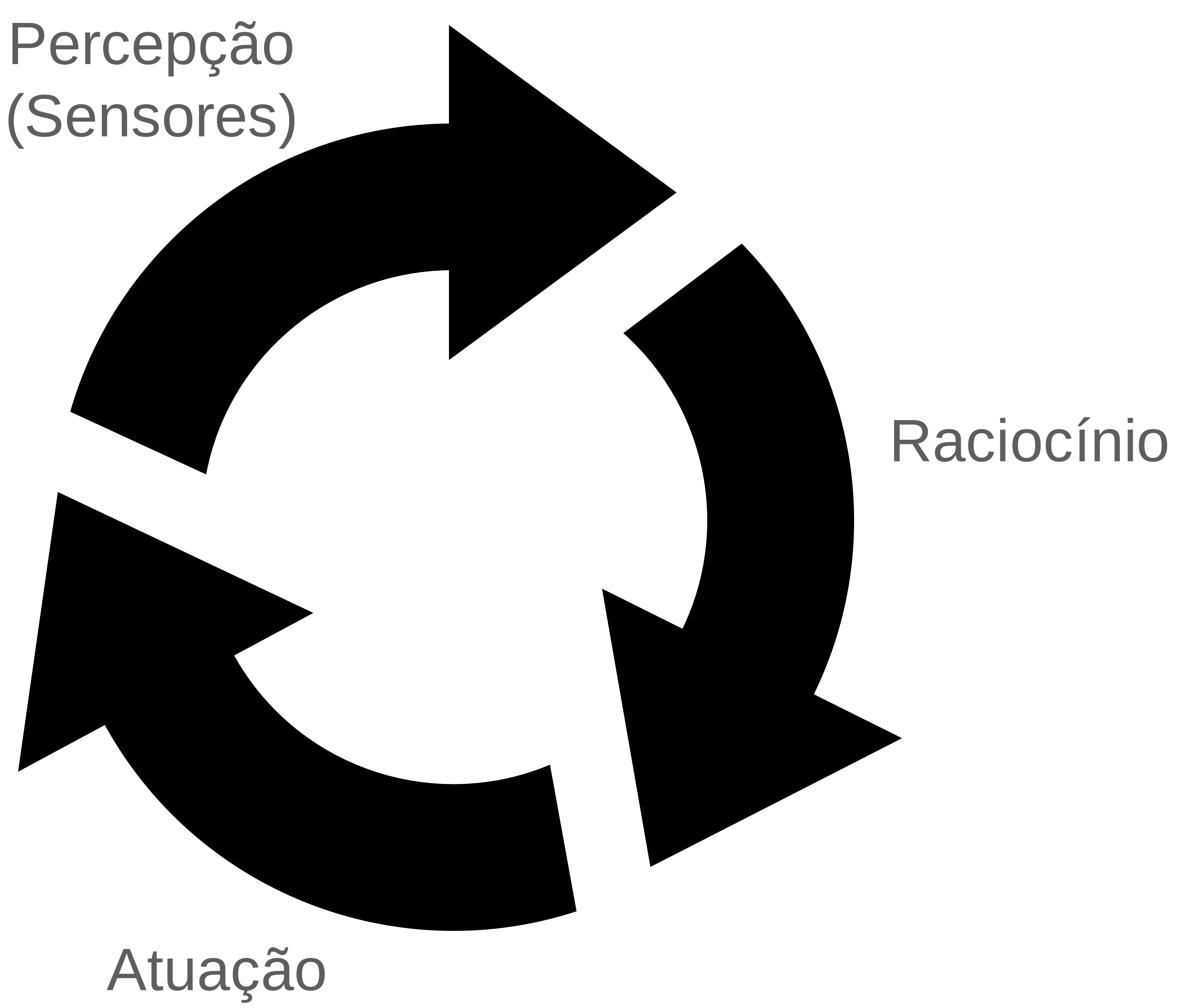
Adaptado de [Cook & Das, 2007]



Automação em smart spaces

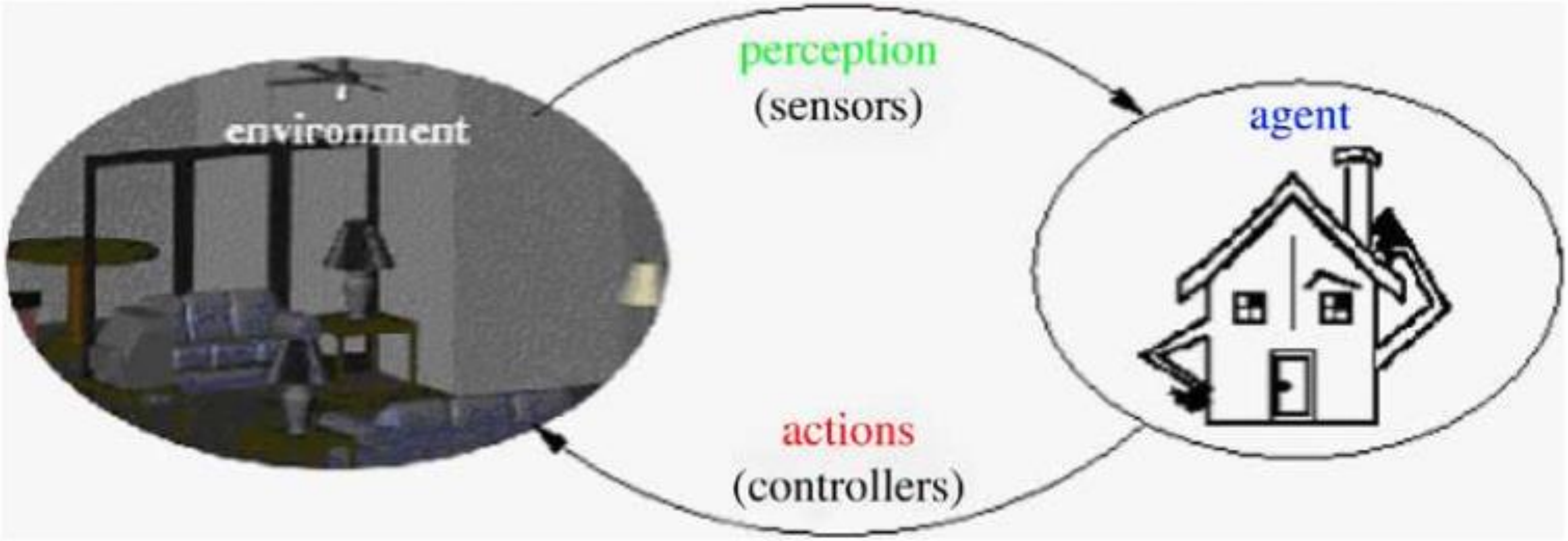
Um ciclo

- Percepção do ambiente
- Raciocínio sobre o estado, objetivos e possíveis ações
- Atuação sobre o ambiente (alterando seu estado)



Smart environments

Relacione com o conceito de “digital twins”



Sensores

Propriedades	Exemplos de variáveis monitoradas pelos sensores
Propriedades físicas	Pressão atmosférica, temperatura, humidade, fluxo de fluidos, sons
Propriedades de movimento	Posição, velocidade, velocidade angular, aceleração
Propriedades de contato	Força, torque, vibração
Presença	Proximidade, distância, movimento, contato, imagens
Propriedades bioquímicas	Agentes químicos, agentes biológicos
Identificação	Características pessoais (reconhec. facial, biometria), RFID, NFC

Obs.: Alguns sensores se prestam a múltiplas finalidades. Ex.: câmeras, microfones

Redes de sensores

- **Requisitos básicos:** rápida (não necessáriamente alta taxa de dados), fácil de instalar e manter, robusta, auto-organizável
- **Limitações:** alto grau de incerteza
  - Recursos limitados nos nós (energia, comunicação, processamento, armazenamento)
  - Incerteza nos dados sensoriados, faixa de sensoriamento, localização, acurácia
  - Flutuações no canal de comunicação sem fio e nas taxas de transmissão
  - Topologia variável (ex.: devido à mobilidade), roteamento adaptativo
  - Segurança
- **Necessidade de processamento "dentro da rede"**
  - Impraticável coletar dados de sensores individuais (grande número de sensores gerando dados a todo instante)
  - Fusão e agregação de dados — por sua vez, pode aumentar a incerteza — tradeoff importante

Smart spaces

Implicações para a computação ubíqua

- Comunicação máquina-máquina (M2M) automatizada
- Dispositivos devem ser imbuídos de "consciência" inerente sobre sua localização atual e sobre o ambiente à sua volta — computação ciente de contexto
- **Desafios:** invisibilidade, descoberta de serviços, interoperabilidade, proatividade, mobilidade, privacidade, segurança, confiança
  - Descoberta de serviços: essencial para "ciência de situação" dos dispositivos no ambiente
- Entidades de hardware e software devem funcionar de forma autônoma, contínua e correta
- Computação ubíqua como plataforma para a construção de *smart spaces*

Serviços cientes de localização

- Serviços que se adaptam à localização e à situação atual
  - Ex.: inferir a atividade atual do usuário

  Dê exemplos
- De forma preditiva: inferir a localização e/ou a atividade futura do usuário
  - Utilizando modelos estocásticos (ex.: cadeias de Markov), detecção de padrões

  Dê exemplos
- Considerando: usuários isolados, grupos de usuários

IMPORTANTE: Localização física/geográfica vs localização simbólica

Interfaces de usuário naturais

- Interação implícita, espontânea — ex.: voz, gestos, movimentos
- Usabilidade e adaptabilidade da interface de usuário
- Ações dos usuários elicitam respostas do ambiente
- Proponha alguns exemplos concretos

Modelagem dos usuários do *smart space*

- Modelo que captura elementos chave do comportamento, humor, sentimentos etc. do usuário
  - Construído principalmente a partir de dados providos por sensores
  - *Data mining* para identificação de padrões, aprendizado supervisionado etc.
- Usado para customizar o ambiente — para atingir objetivos de automação, segurança, eficiência energética etc.
- Permite definir um comportamento "normal" — facilita a detecção de anomalias
- Modelo adaptativo → ambiente adaptativo

Tomada de decisão

Exemplos comuns

- If-this-then-that (ex.: IFTTT)
- Políticas ECA (Event-Condition-Action)
- Planejamento baseado em IA
- Redes neurais artificiais e aprendizado por reforço

Smart spaces - O conceito completo

- Não apenas um ambiente capaz de reagir a estímulos provenientes de sensores
- Não apenas um ambiente rico em informação e processos automatizados
- Essencial:
  - Continuidade
  - Uso transparente
  - Suporte intrínseco à mobilidade, sem a necessidade de intervenção do usuário

Exercício

“An employee wants to show a set of figures to his/her manager. As he/she app roaches his/her office, a quick glance at his/her tab confirms that the boss is in and alone. In the midst of their conversation, the employee uses the tab to locate the data file on the network server and to request a printout. The system sends his/her request by default to the closest printer and notifies him/her when the job is finished.” [Want et al., 1995]

- Este cenário é compatível com a visão de ambiente inteligente? Por que? Que limitações ele possui?

Leitura

Smart Spaces in Ubiquitous Computing

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ABSTRACT

In this era where development of Smart Spaces is an appealing goal in different disciplines, understanding its use in the context of Ubiquitous Computing is essential for its' comprehensive exploration. Although the term 'Smart Spaces' has been frequently used by the Ubiquitous Computing research community, there is a gap between its use and the underlying principles of Ubiquitous Computing. The majority of researchers focus their research on providing information rich environments and ignore the need to continuously support computational tasks and resources within the space. This paper explores the different principles and characteristics of Ubiquitous Computing and analyses a variety of Smart Space research. The paper identifies the key components and attributes of a true Smart Space and provides a definition of Smart Spaces in the context of Ubiquitous Computing.

Keywords: Smart Spaces, Intelligent agents, User Mobility, Ubiquitous Computing and Reasoning Mechanism.

1. Introduction

Current developments in technologies and infrastructures for Ubiquitous Computing (Ubicomp) have motivated the invention of different applications that are becoming highly useful in human life. The state-of-the-art of these inventions is the development of environments that understand and react to human desires, *Smart Spaces*. These environments are useful in areas from entertainment to work optimisation and to assisting elderly and disabled people.

Although many research communities have leveraged Ubicomp benefits to develop so called Smart Spaces, the definition for Smart Spaces meaning is quite vague. Many researchers focus on providing an information rich environment that ignore user mobility within the space. User mobility involves providing continuous access to computational tasks and resources within these environments. Such vague and incomplete definition of the term Smart Spaces fails to fully identify the potential of Ubicomp for supporting and improving daily life of individuals. Furthermore, it brings about confusion to novices in the Ubicomp research community and individuals outside the Ubicomp community.

Therefore, a better understanding of Smart Spaces in the context of Ubicomp is the cornerstone for the growth of research in Smart Spaces in Ubicomp. In this paper we present and review Smart Spaces in the context of Ubicomp and propose a formal definition for Smart

How Smart are our Environments? An Updated Look at the State of the Art

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Abstract

In this paper we take a look at the start of the art in smart environments research. The survey is motivated by the recent dramatic increase of activity in the field, and summarizes work in a variety of supporting disciplines. We also discuss ongoing challenges for continued research.

1 Introduction

Designing smart environments is a goal that appeals to researchers in a variety of disciplines, including artificial intelligence, pervasive and mobile computing, robotics, middleware and agent-based software, sensor networks, and multimedia computing. Advances in these supporting fields have prompted a tremendous increase in the number of smart environment projects. Because of the rising popularity of the topic and a growing desire for successful projects in the marketplace, we offer an updated look at the state of the art in smart environments.

We define a smart environment as *one that is able to acquire and apply knowledge about the environment and its inhabitants in order to improve their experience in that environment* [88]. The components of a smart environment are shown in Figure 1.

Automation in a smart environment can be viewed as a cycle of perceiving the state of the environment, reasoning about the state together with task goals and outcomes of possible actions, and acting upon the environment to change the state. Perception of the environment is a bottom-up process. Sensors monitor the environment using physical components and make information available through the communication layer. The database stores this information while other information components process the raw information into more useful knowledge (e.g., action models, patterns). New information is presented to the decision making algorithms (top layer) upon request or by prior arrangement. Action execution flows top-down. The decision action is communicated to the services layers (information and communication) which record the action and communicates it to the physical components. The physical layer performs the action with the help of actuators or device controllers, thus changing the state of the world and triggering a new perception.

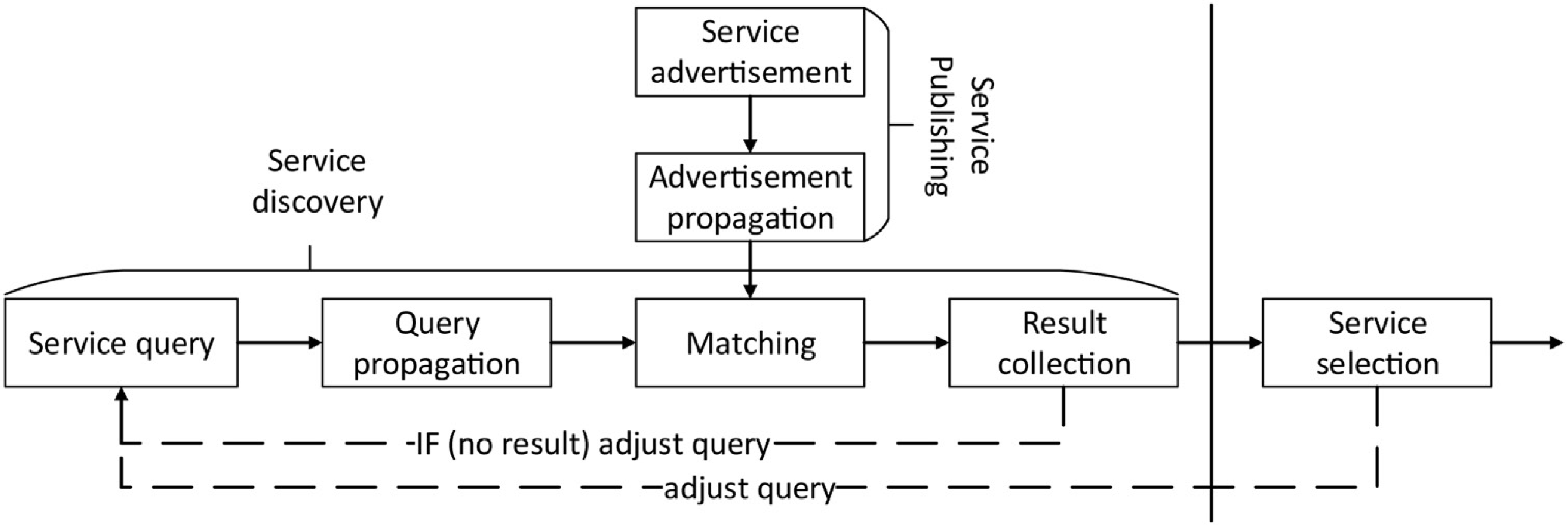
1

Tarefa

- O que muda no conceito geral de *smart space* com a introdução de computação em nuvem?
- Pesquise e compare os conceitos de *smart home*, *smart building* e *smart city* com o conceito geral de *smart spaces*.
- Qual o papel de *“digital twins”* em *smart spaces*?
- Proponha dois cenários práticos diferentes para ilustrar o conceito de *smart spaces* combinado com o uso de *digital twins*.

Descoberta de Serviços em smart spaces

O processo geral de descoberta de serviços



Descoberta de serviços

Idéia geral

- Conectividade é essencial, mas não é tudo
- Necessário que os dispositivos possam se encontrar (i.e., seus *endpoints* de interação, os serviços que oferecem) no ambiente
- Abordagem simplista: usar um motor de busca (ex.: Google)
  - Problemas: escalabilidade, privacidade (a informação sobre os dispositivos precisaria ser pública), tempo até a indexação pelos *crawlers*
- Descoberta deve ser local, dentro do ambiente
- E nomádica: usuário móvel capaz de descobrir serviços locais onde estiver

Arquitetura geral de descoberta de serviços

Elementos principais

- Protocolo de descoberta de serviços
  - Unicast
  - Multicast
- Desejável: Suporte para proxy — em caso de indisponibilidade temporária do dispositivo procurado

- **Arquitetura de sistema:**
  - Centralizada — descrições de serviços armazenadas em um ou mais servidores de descoberta (serviços de diretório)
  - Descentralizada — descrições de serviços armazenadas nos próprios SPs
  - Hierárquica — combinação das duas acima

Exemplos de protocolos de descoberta

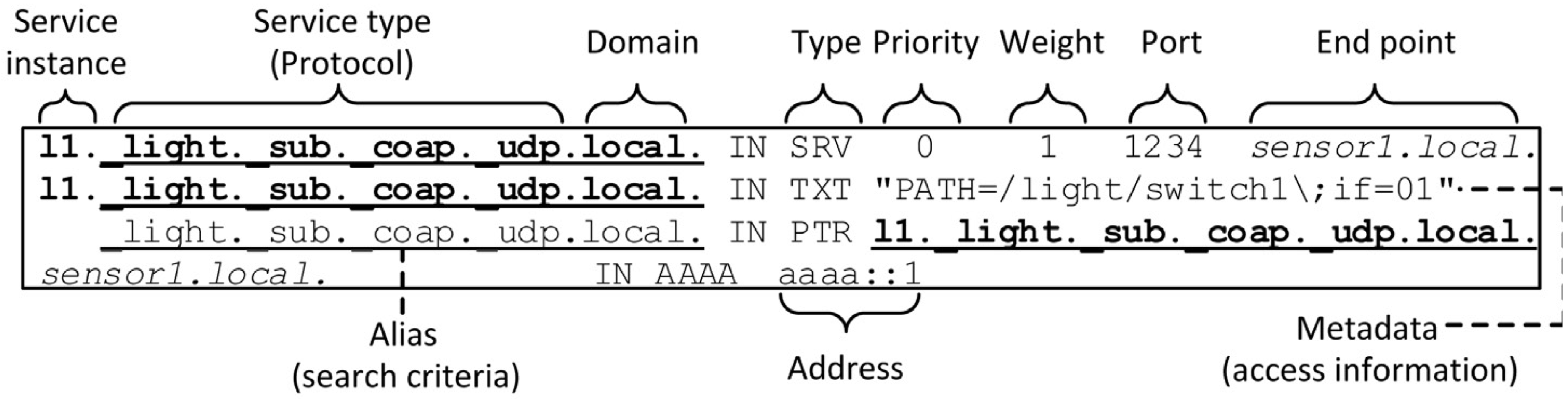
Protocol	Architecture	Discovery Mechanism	Registration Mechanism	Overhead	Description	Interoperability
mDNS/ DNS-SD [2,3]	Distributed	Multicast	Multicast	DNS packets	DNS-SD	Yes
UPnP [6]	Hierarchical	Multicast or unicast	Multicast	Heavy transport protocol	URL	Yes, gateways
Jini [7]	Centralized	Multicast or unicast	Multicast or unicast	Heavy protocol	Java	Yes
SLP [8]	Distributed or centralized	Multicast or unicast	Multicast or unicast	Translation agents	String, XML	Yes
SDP [9]	Distributed	Unicast	Unicast	SDP server discovery (unknown)	UUID	No

Exemplos de protocolos de descoberta

Protocol	Localization	Mobility	Proxy Support	Energy-Aware	Low Resource
mDNS/DNS-SD [2,3]	Domain name or service description	Time-to-live expiry, service invalidation	Yes	No	Yes
UPnP [6]	Domain name	Time-out expiry, periodic advertisements	No	No	Yes
Jini [7]	No	Time-out expiry	Yes	No	No
SLP [8]	Yes	Time-out expiry	Yes	No	Yes
SDP [9]	Yes (one hop)	No	No	Yes	Yes

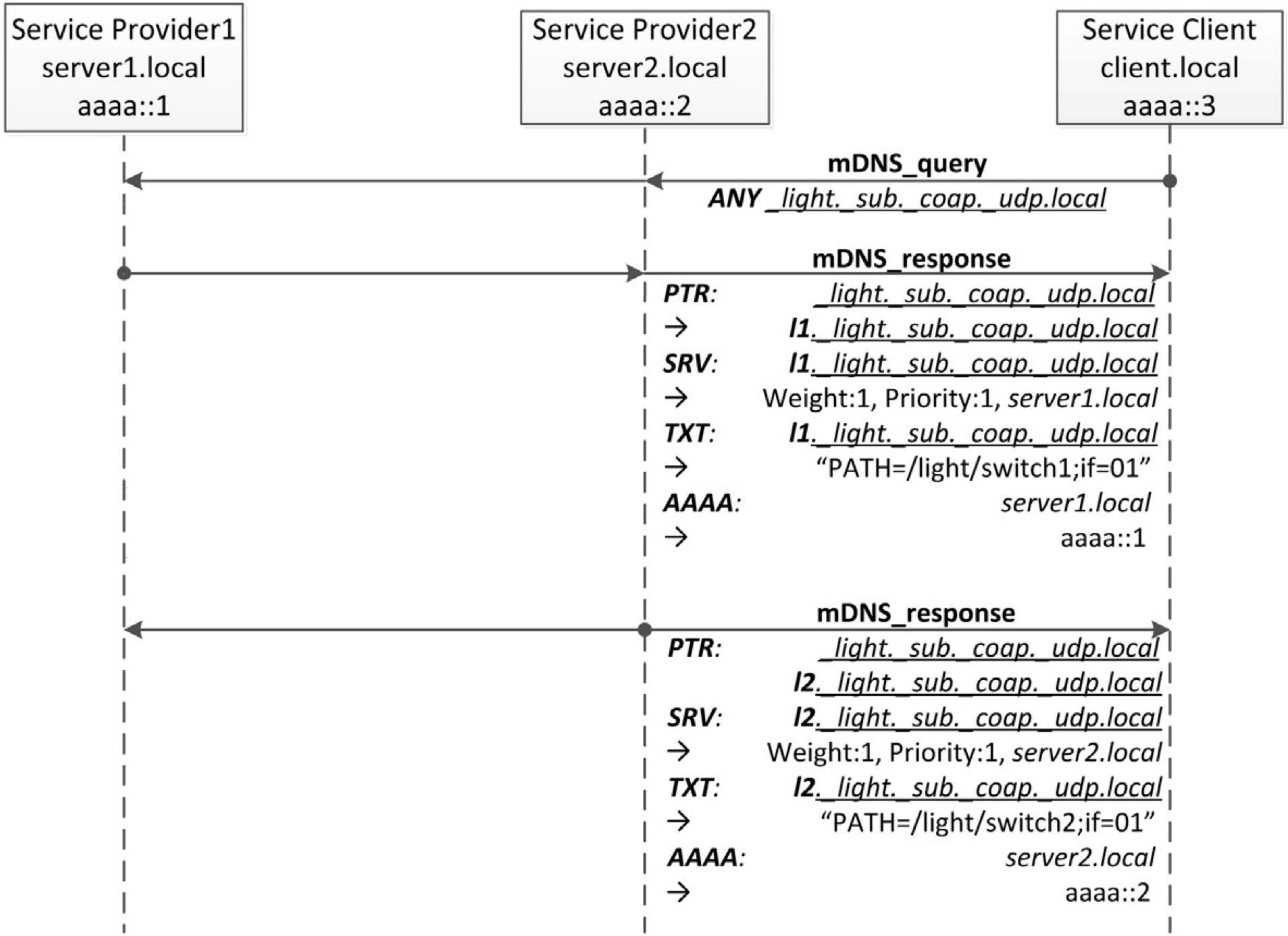
Exemplo: mDNS / DNS-SD

- **mDNS**: extensão do DNS para redes locais, descentralizado, multicast
- **DNS-SD**: permite associar nomes a descrições de serviços (enquanto o DNS convencional associa nomes a endereços) — dois novos tipos de registro de recursos (RR): SRV e TXT



mDNS / DNS-SD

Exemplo de operação



mDNS / DNS-SD

Algumas implementações

Table 4.4 Code and Memory Footprint of Different mDNS/DNS-SD Implementations

Implementation	Code	Memory
Bonjour by Apple	500KB[a]	/
Ethernet Bonjour for Arduino	14KB	/
uBonjour for Contiki [17]	7.69KB	0.4KB
mDNS/DNS-SD for Contiki[b]	6.51KB	0.7KB

mDNS/DNS-SD, Multicast Domain Name System with DNS-Based Service Discovery.
[a]*Based on the size mDNSResponser.exe on 64-bit platforms. Memory information is unavailable.*
[b]*Available at https://github.com/mstolikj/contiki*

Leitura

CHAPTER

NOMADIC SERVICE DISCOVERY IN SMART CITIES 4

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1 INTRODUCTION

The concept of "Smart Cities" refers to cities that enhance their processes by digital technologies, thus reducing cost and increasing well-being [1]. In general, the term "smart" refers to improvements through digital technology and can be applied to any process or service (eg, smart energy or smart transport). The main technological drivers for the emergence of Smart Cities are the vast embedding of electronics in physical objects, their imminent *connectivity*, and the availability of *data-based services*.

Connectivity includes the general ability for devices—embedded or not—to communicate. We are used to the connectivity of phones, game computers, and other handhelds to the Internet, although this trend started less than 10 years ago. The Internet is now being extended to include the increasing number of devices that are embedded in the physical world, in what is commonly referred to as the "Internet of Things" (IoT). The connectivity thus is the basis of data-based services that are services backed up by large-scale data collection. For example, predictive (smart) energy management is based on data collected over a long period of time.

In this chapter we concentrate on connectivity, and on finding and using digital services within a smart city context. A smart city has a digital infrastructure for use by its own internal processes but also available to mobile users (individuals, vehicles, buses) and more static users (shops, public facilities). Digital services are available through this infrastructure and can be as varied as the following examples:

1. information services such as the website of the shop I am looking at now;
2. parking spot location and status, within the vicinity, plus the ability to reserve one;
3. access to local lighting actuators;
4. access to local air quality measurements.

This list can obviously be extended with (location-dependent) services of interest to mobile users. If we classify both service providers (SPs) and users as either static or mobile, then the static/static case is much alike the current Internet while the other three cases require new approaches to service discovery (SD) and naming in order to facilitate an efficient matching of SP and user.

In Fig. 4.1 the process and goal of SD is highlighted: service seekers issue queries matched by SPs in a distributed context where neither one knows the existence of the other. Service discovery protocols (SDPs) achieve this goal by defining (1) a common language for describing services and selection criteria; (2) a common protocol for exchanging service descriptions between service clients (SCs) and SPs; and (3) rules for matching service descriptions with the selection criteria.

Smart Cities and Homes. http://dx.doi.org/10.1016/B978-0-12-803454-5.00004-3

Leitura suplementar

Para tarefa

Journal of Innovation Management (2017) 5 14-34 ● *Digital Twins* by Shoumen Palit Austin Datta

Emergence of Digital Twins

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Keywords. Digital Economy, Digital Twins, IoT, Agents, AI, Analytics, Cognitive Firewall, Cognitive Compass, Data

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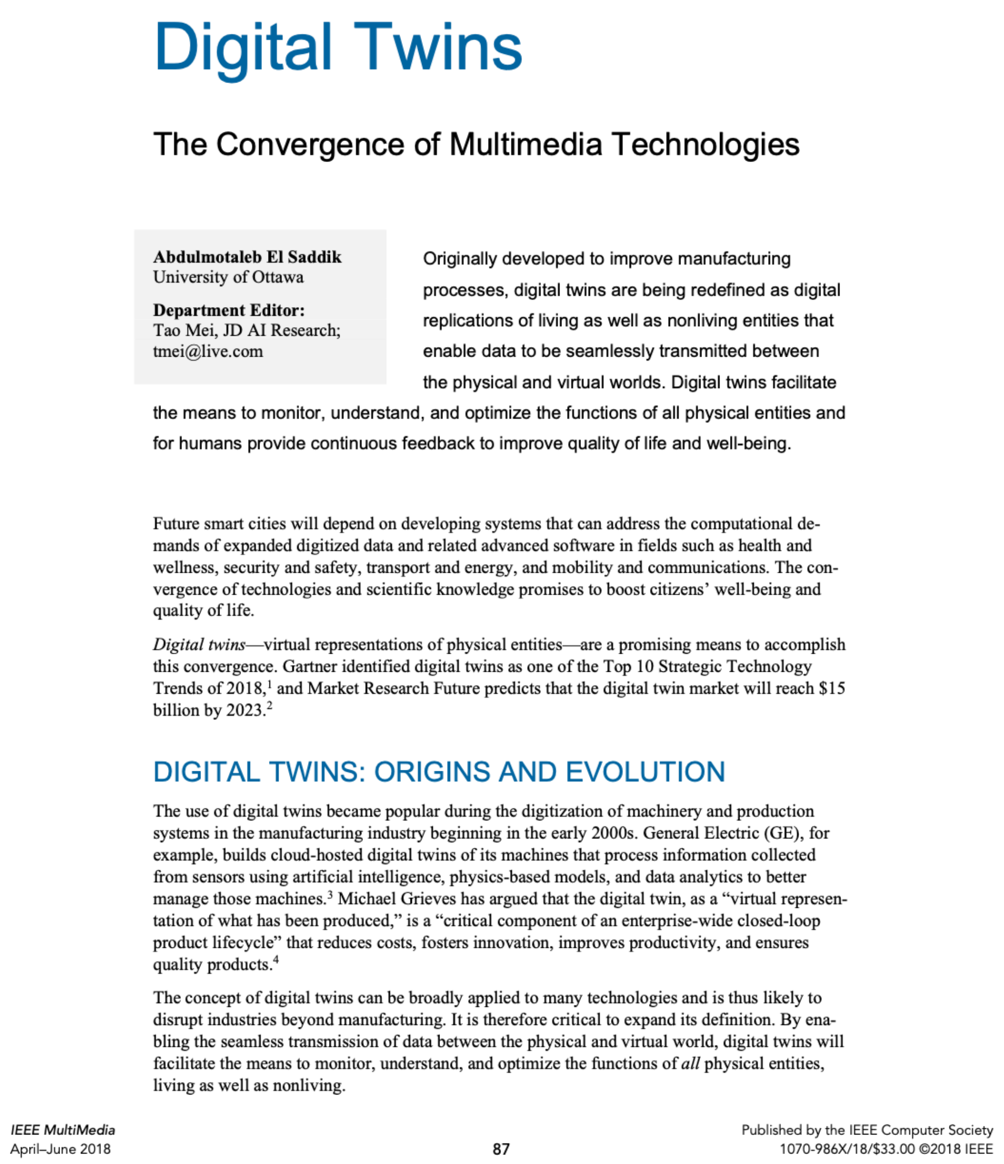

Digital Twins

The Convergence of Multimedia Technologies

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Originally developed to improve manufacturing processes, digital twins are being redefined as digital replications of living as well as nonliving entities that enable data to be seamlessly transmitted between the physical and virtual worlds. Digital twins facilitate the means to monitor, understand, and optimize the functions of all physical entities and for humans provide continuous feedback to improve quality of life and well-being.

Future smart cities will depend on developing systems that can address the computational demands of expanded digitized data and related advanced software in fields such as health and wellness, security and safety, transport and energy, and mobility and communications. The convergence of technologies and scientific knowledge promises to boost citizens' well-being and quality of life.

Digital twins—virtual representations of physical entities—are a promising means to accomplish this convergence. Gartner identified digital twins as one of the Top 10 Strategic Technology Trends of 2018,[1] and Market Research Future predicts that the digital twin market will reach $15 billion by 2023.[2]

DIGITAL TWINS: ORIGINS AND EVOLUTION

The use of digital twins became popular during the digitization of machinery and production systems in the manufacturing industry beginning in the early 2000s. General Electric (GE), for example, builds cloud-hosted digital twins of its machines that process information collected from sensors using artificial intelligence, physics-based models, and data analytics to better manage those machines.[3] Michael Grieves has argued that the digital twin, as a "virtual representation of what has been produced," is a "critical component of an enterprise-wide closed-loop product lifecycle" that reduces costs, fosters innovation, improves productivity, and ensures quality products.[4]

The concept of digital twins can be broadly applied to many technologies and is thus likely to disrupt industries beyond manufacturing. It is therefore critical to expand its definition. By enabling the seamless transmission of data between the physical and virtual world, digital twins will facilitate the means to monitor, understand, and optimize the functions of *all* physical entities, living as well as nonliving.

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Smart City Digital Twins

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***Abstract*—Driven by the challenges of rapid urbanization, cities are determined to implement advanced socio-technological changes and transform into *smarter cities*. The success of such transformation, however, greatly relies on a thorough understanding of the city's states of spatiotemporal flux. The ability to understand such fluctuations in context and in terms of interdependencies that exist among various entities across time and space is crucial, if cities are to maintain their smart growth. Here, we introduce a *Smart City Digital Twin* paradigm that can enable increased visibility into cities' human-infrastructure-technology interactions, in which spatiotemporal fluctuations of the city are integrated into an analytics platform at the real-time intersection of reality-virtuality. Through learning and exchange of spatiotemporal information with the city, enabled through virtualization and the connectivity offered by Internet of Things (IoT), this *Digital Twin* of the city becomes smarter over time, able to provide predictive insights into the city's smarter performance and growth.**

***Keywords*—Digital Twins, Interdependence, IoT, Smart Cities, Spatiotemporal Flux.**

I. Introduction

Cities, responsible for much of the world's total resource consumption, are rapidly growing in size and population, resulting in major impacts on our economic, environmental, and social future. The global consequences of the rapid urbanization and unprecedented increase in human activities create complex interdependencies between humans, infrastructures, and technologies, which will inevitably be substantially different from that in today's cities and may result in increasing uncertainties, unreliable predictions and poor management decisions. In order to cope with the staggering complexities, along with global sustainability concerns, many cities are deliberately implementing technological advancements in their operations towards smarter performance, transforming into *smart cities* that adhere to a smart growth agenda. However, success of such transformation requires the ability to understand and manage new challenges that emerge in time and space. Here, we explore the key dimensions of this phenomenon in a reality-virtuality integrated paradigm.

II. Smart Cities

Smart Cities, as a concept, can be traced back to the conception of *wired cities* [1] in the 1980s, and *digital cities* [2] in the early 1990s, followed by the *smart growth* movement [3]. Today, smart cities are envisioned to ensure that the expected increase in urban population to nearly 6.3 billion by 2050 [4], combined with the resulting complexities stemming from human activities, are managed to effect positive outcomes in allocating resources, providing security, maximizing services, facilitating human activities, and preventing disruption, while continuously adapting to the changing behaviors of the citizens. Leveraging effective instrumentation, interconnection, and collective intelligence of the city [5], smart cities are expected to improve operational efficiency and quality of life. However, cities, as complex adaptive systems, experience several changes of states in their operations with respect to individuals' activities that are increasing due to the dynamic pressure of population growth. Therefore, successful transformation of cities to smart cities demands advancing city performance through integration of human, infrastructure and technology (Fig. 1). Both spatial and temporal performance equilibria are subject to vulnerabilities that make human-infrastructure-technology systems susceptible to changes of state, or collapses. A better understanding of the underlying drivers of this process will facilitate the identification of the systems' reactive, recovery, and adaptive capacities across time and space.

III. Spatiotemporal Flux

Increases in size, diversity and complexity of data being spatiotemporally generated every day from city infrastructures and human activities at such a rapid rate requires a paradigm shift in how the infrastructure service interdependencies are understood, influenced, and ultimately managed through the connectivity and interoperability offered by IoT. However, we lack insights into such interdependencies due to lack of data integration approaches that take into account the space-time fluctuations, as well as the behavior of the human population in relation to the city infrastructure. Establishing smarter city infrastructure through technology requires citizen engagement as well as a clear picture of demand diversity. Given that cities are in a continuous state of flux, how can we anticipate future patterns of human-infrastructure-technology interactions? With the growing amounts of data being generated, it is not sufficient to anticipate trends; instead, we need to anticipate and incorporate flux in both space and time dimensions, understanding the fluctuating interdependencies, and contextualize such variations.

A. Context

Research on smart cities spans a diverse array of topics, mainly because it requires broad, societally contextualized data

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On building support of digital twin concept for smart spaces

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***Abstract*—Inherited from industry 4.0 domain, digital twin concept will represent an important step forward in what we have understood as smart city concept. In this paper we present our ongoing work on extending a monitoring smart city middleware to a digital twin platform for smart cities. The reader will learn some key issues of this new concept in the field of smart cities including some open questions that need to be investigated about the user interaction with digital twin concept.**

***Index Terms*—smart spaces, ambient intelligence, digital twin, 3D representation.**

I. Introduction

The digital twin [1] concept is taking importance in several domains (Industry, Cyber Physical System, Simulation, etc.) due its important advantages for fostering IT service development, simulation, testing, reduce maintenance issues, user's privacy, etc. As a general concept, a digital twin is a digital representation of a physical asset. So, with different level of accuracy, a digital twin can:

- show users the state of the physical asset at real time.
- interact with the physical asset.
- model the behaviour of the physical asset/space.
- simulate the response of the physical asset to different events.

In the smart space domain, a digital twin is useful at different vertical domains (maintenance of buildings, forecasting anomalous situations, to support emergency situations, etc.) but we have to deal with several challenges to pass from labs to real scenarios.

The project Citsim (ITEA3 European project)[1], recently finished, put the keystones for building smart city digital twins (3D visualization, IoT middleware, citizens services, etc.). In this paper we explain our ongoing efforts to extend Citisim platform to modelize/building a smart city's digital twin.

Two are the main contributions of this paper, first we propose an overall data model to provide support to digital twin building of a smart space from an engineering approach, second we provide a 3D toolchain for automatic smart city 3d model generation from LiDAR/openstreet map data set. We also describe our first experiences on building a digital twin of a smart space, first with a mock-up and currently with a building.

II. State of Art

Currently, Geographic Information Systems [2] (GIS) and Building Information Modelling [3](BIM) are broadly used in smart city planning, management, etc. Both type of systems are working mainly with statistical information.

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[1] http://www.citisim.org/

Obs.: Links no Moodle (Turing)

Projeto

Idéias iniciais

- Projetar e construir um “digital twin” de um ambiente físico.
- Construir uma aplicação ubíqua — com continuidade transparente entre dispositivos.
- Controle autônomo de dispositivos do ambiente com base em sensores e regras
- Aplicação móvel que se adapta à localização do usuário
- *Offloading* the computação entre dispositivo móvel, fog e cloud