Discovering Good Links Between Objects in the Internet of Things

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bstract The Internet of Things is an emerging aradigm allowing the control of the hysical world via the Internet rotocol and both h man-to-machine and machine-to-machine comm nication In this scenario one of the most challenging iss es is how to choose links among objects in order to g arantee an effective access to services and data In this a er we resent a new selection criterion that im roves the classical a roach To reach this goal we e tract knowledge coming from the social network of h mans as owners of objects and we e loit a recently roven ro erty called interest assortativity The reliminary e erimental res lts re orted in this a er give a rst evidence of the effectiveness of o r a roach which erforms better than classical strategies This is achieved by choosing only not red ndant links in s ch a way that network connectivity is reserved and ower cons m tion is red ced

1 INTRODUCTION

The Internet of Things refers to a new aradigm com- osed of networked interconnection of everyday objects which are often smart e g e i ed with bi - ito s intelligence This innovative scenario will increase the bi ity of the Internet by integrating every object for interaction via embedded systems Moreover it will lead to a highly distrib ted network of devices where machine-to-machine and h man-to-machine comm nication will be ossible

One of the basic roblems to face is how to b ild the Internet of Things Indeed the choice of a strategy to drive the formation of comm nities of objects has a direct im act on different as ects relevant from the a lication oint of view rst desiderata is that the network of objects has a s f cient connectivity degree to g arantee that the otential bene ts arising from the comm nication among objects are not inhibited ccording to this rinci le one co ld think of a highly connected network ideally a com- lete gra h owever the trade-off to solve regards the limited com tational and ower ca abilities of smart objects for which the n mber of connections sho ld be minimi ed

The ty ically ado ted a roach to establishing a direct connection between two objects is mainly based on ro imity nion 2005 hang et al 2011 vangelos et al 2011 Instead we de ne a new strategy leveraging the ro erties of the objects and estimating how m ch similar ro erties sho ld enforce a direct link between two objects This is done by matching object ro erties to h man interests and by meas ring the assortativity degree of s ch interests in the h man social network of owners s osed to be Twitter B ccaf rri et al 2015a The claim is that the higher s ch an interest assortativity B ccaf rri et al 2015b the higher the otential bene- t of directly connecting the corres onding objects This rocess allows s to *discover* good links between objects which g arantee good network connectivity among *similar* objects by limiting the node degree and then the related inef ciencies We tested the above strategy e erimentally and obtained very romising res lts ccording to a n mber of social-network-analysis meas res B ccaf rri et al 2015c we concl de that the network of objects created by means of o r a roach is m ch better than the network obtained by sing the classical one

1.1 Motivating Example

To better e lain o r goal we resent the following real-life sit ation

`Francis` is a r nner e likes meas re his erformance and is es ecially interested in knowing his s eed d ring his activity e is sed to meas re his advancement by a smart bracelet in com anion to his

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smart hone Both ens re him a f ll tracking of his ersonal activity data e has a Twitter acco nt and he is follower of many s ortive man ersonal coach instr ctor beca se he wants to stay well informed abo t all news in the eld

`Lucy` is always watching her weight She likes to be in t and to eat biologic food she likes read abo t n trient information on food herbs ro erties cosmetics se and so on To accom lish her goal she is sed to ado t a series of mobile a s to track abo t food s orts and to stay informed abo t these to ics On Twitter for instance she follows famo s actresses ersonal trainers and n tritionists to get well informed abo t these to ics

`Steven` is a st dent e s ends a lot of time staying sit and working on the la to e is worried abo t ass ming a right ost re then he had bo ght a in able to give a vibration whenever his ost re is wrong or he is staying to long e has a Twitter acco nt and he is follower of healthy rod cts in general from ost re to food to s orts and so on e does not like to ractice s orts

By following the interest assortativity a roach we fo nd o t health like a common macro-interest shing on this to ic of interest we are able to s ggest friendshi between these com onents s orting their owners in achieving their goals however they look like tr ly different In fact `Francis` and `Lucy` have never considered the im ortance of a right ost re for the wellbeing conversely `Steven` does not take care eno gh abo t s orts and food while he is a very sedentary erson What the new a roach allows is the establishment of friendshi between this series of devices to allow the f ll accom lishment of ersonal goals of everybody s ggesting them new ones and novel ways to accom lish the same res lts

This is disc ssed in the ne t section in which we show that in the cases like those described above the knowledge ty ically sed to establish a connection between objects wo ld rod ce nsatisfactory res lts or e am le by considering ro imity i e the fact that the objects meet each other a given n mber of times with a s f cient fre ency we sho ld concl de that there is no reason to connect the above objects Indeed robably the above objects never meet

1.2 Structure of the Paper

The lan of this a er is as follows In Section 2 we resent o r a roach to chose links in a IoT environment Section 3 describes the reliminary e erimentation carried o t to st dy the effectiveness of o r techni e Section 4 deals with literat re related to o r work inally in Section 5 we draw o r concl sions

2 DISCOVERING GOOD LINKS

ccording to the Internet-of-Thing aradigm an entity on a network has to be noti ed of the availability of desirable services or devices on the network in order to form a link Ty ically the fact that two objects get in to ch somewhere and sometimes maybe beca se the corres onding owners meet in a certain location is eno gh to trigger with a given threshold the establishment of a link between the two objects nion 2005 hang et al 2011 vangelos et al 2011 This ro erty is called *proximity* The aim of this section is to identify ossible enhanced ways to discover otentially bene cial links To do this reliminarily we consider which are the candidate ro erties e isting in the literat re we can se to b ild a more com le model They are *(i)* ro imity *(ii)* homogeneity i e they are the same kind of object created by the same man fact rer *(iii)* ownershi i e they belong to the same ser *(iv)* friendshi i e owners are m t al friends in a social network

rg ing that the decision regarding the insertion of a link between two objects co ld rely on a mi of the above ro erties we de ne a decision f nction to decide whether a link between two objects $\langle x, y \rangle$ has to be inserted or not

Observe that all the above ro erties give s some information abo t the direct relationshi between two objects O r ro osal aims to se also some indirect knowledge coming from the social network of owners to s ort the com tation of the above decision f nction B ccaf rri et al 2016b In addition des ite the classical selection criteria that are based on the sole ro imity we se all the above direct ro erties Therefore we introd ce two meas res which we combine to com te the aimed decision f nction These are

1 $T^{dir}_{x,y}$ which derives from the *direct* knowledge abo t objects and owners and
2 $T^{ind}_{x,y}$ which encodes some *indirect* knowledge

s indirect knowledge we e loit a recently roven ro erty occ rring in online social networks called *interest assortativity* B ccaf rri et al 2016a ccording to this res lt it is ossible to have a meas re of the correlation between a given h man interest and the resence of links between h mans

To e loit the above indirect ro erty we need to match objects to h mans in s ch a way that interests are someway reserved To do this we de ne a ta onomy on to of the ro erties and or aims of objects

This ta onomy allows s to associate each object x with a set of h man interests I_x belonging to a given domain I derived from the owners social network Clearly the following reasoning is valid only if all the involved h mans have a social network acco nt To b ild this ta onomy we consider how many times a ser with a certain interest say i owns a given object x This way we can de ne an *occurrence* degree O_i^x of i w r t x as the ratio between the n mber of sers with interest i owing x and the total n mber of occ r- rences of the interest i in the network

Therefore given two objects $\langle x,y \rangle$ we com te the overla ing set of associated interests as $I_{x,y} = I_x \cap I_y$ and for each common interest $i \in I_{x,y}$ we com- te the assortativity level IA_i of i in the considered social network and the common occ rrence degree $O_i^{x,y}$ de ned as the mean between O_i^x and O_i^y

t this oint we are ready to de ne how $T_{x,y}^{ind}$ is com ted In artic lar

$$T_{x,y}^{ind} = \sum_{i \in I_{x,y}} \frac{O_i^{x,y} \cdot IA_i}{|I_{x,y}|}.$$

In words $T_{x,y}^{ind}$ is obtained as a mean between as- sortativity degrees of common interests weighted by the common occ rrence degrees Since objects $\langle x,y \rangle$ are both related to $I_{x,y}$ we e ect that the higher the val e $T_{x,y}^{ind}$ the higher the linking ower of interests in $I_{x,y}$ sho ld be also for objects

inally we combine the two val es $T_{x,y}^{dir}$ and $T_{x,y}^{ind}$ to obtain o r boolean f nction to decide whether to add a link between the two objects S eci cally given two objects $\langle x,y \rangle$ a new link is established if

$$F(T_{x,y}^{dir}, T_{x,y}^{ind}) \geq th$$

where th is a s itable threshold val e and F is a a- rameter of o r model to set by e eriments

3 EXPERIMENTS

In this Section we describe o r e erimental cam- aign carried o t in order to validate o r a roach In artic lar we started from a set of h mans and ob- jects and we b ilt two networks

1 a network of objects obtained by adding links ac- cording to o r a roach based on interest assorta- tivity
2 a network of objects formed thro gh the classical ro imity-based criterion

The obtained res lts showed that the ality of the rst network is better in terms of ef ciency than the second one In the following we will e lain which is the meas res ado ted to eval ate the network ef - ciency

3.1 Testbed and Dataset

O r e eriments were carried o t on a machine e i ed with a 2 ad-Core 5440 rocessor and 16 GB of M The o erating system was Lin b nt Server 14 04 4 LTS with kernel version 4 2 0-35 ava irt al Machine version 1 0 45 64-Bit We wrote o r code in ava by also e loiting some fea- t res of Neo4 neo 2016 a gra h database manage- ment system

or o r e eriments we sed a Neo4j gra h data set called *GraphofThings* consisting of nodes cat- egori ed by one or more labels and connected by instances of directed relationshi s We obtained it from a gith b re ository maintained by the Gra h l- chemist gro Gra 2016

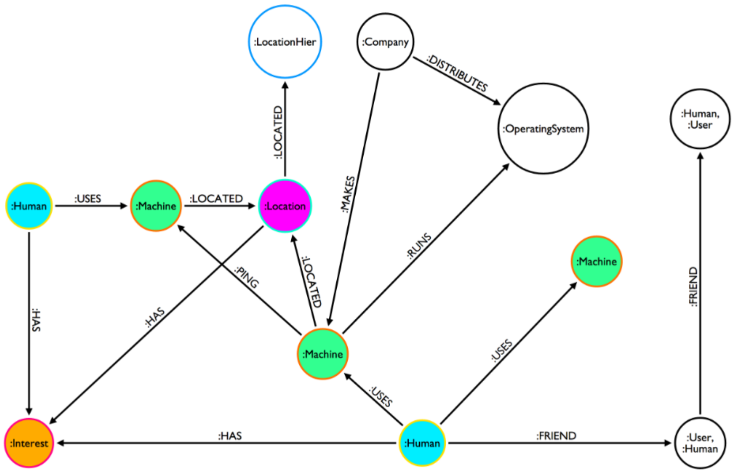
ig re 1 shows an instance of the gra h model re resenting interactions i e arcs between entities i e nodes sed in o r eriments

or o r e erimental cam aign we needed only some of the entities showed in the above schema In artic lar the nodes we took into consideration are

- *Human.* ser e i ed with a device
- *User.* node re resenting a social network ro le i e acebook Linkedin Twitter etc Observe that not all the sers are h mans
- *Machine.* node that indicates any wearable or mobile device It osses a tag *type* that indicates the family which it belongs to
- *Interest.* node that holds a single *interest* cate- gory
- *Location.* node that indicates a hysical lace It can be e i ed with a n mber of attrib tes in- dicating for e am le an event an activity a store a ark etc

The main relationshi s involved in o r dataset are

- *Uses.* directed relationshi between a h man and any n mber of devices he wears
- *Located.* n action taken by a device im lying that a ser were in a s eci c location
- *Friend.* n im licitly bi-directional relationshi im lying a connection in a given social network
- *Has.* relationshi im lying that a ser has a s eci c interest



ig re 1 Gra h re resentation of the *GraphofThings* nodes and relationshi s

3.2 Results and Analysis

s rst ste we generated the network of h mans and objects according to the classical ro imity criterion S eci cally we added a link between two machines if they had got in to ch at least once in a certain location

Secondly we generated the network of objects by following o r criterion This task re ired some more com le ste s Indeed for two objects $\langle x,y \rangle$ we added a link between them only if $T^{dir}_{x,y} \cdot T^{ind}_{x,y} \geq th$ where $T^{dir}_{x,y}$ is a boolean f nction ret rning 1 if x and y had got in to ch in a given location at least once or their owners have a friendshi relation in the corre s onding social network 0 otherwise In other words for this rst investigation we consider only ro imity and friendshi as direct ro erties and we set the f nction F by the sim le rod ct between $T^{dir}_{x,y}$ and $T^{ind}_{x,y}$

Once both the networks were created we mea s red some ality arameters to com are them Table 1 shows the res lts of o r analysis carried o t by e loiting CIN T ci 2016 a well-known software ackage for the analysis of social network data

rom the res lts re orted above we can observe that the network b ilt by sing the assortativity-based a roach shows a lower average degree and th s a lower density level ltho gh in general high val es of *density* im ly a higher robability of reaching target nodes this has also a negative im act on the network ef ciency Indeed the higher the val e of density the higher the traf c level and d lication in broadcast comm nications

We can make a similar reasoning for all arameters that have a direct relationshi with the n mber of oint-to- oint comm nications that nodes have to maintain s ch as *average degree* Observe that network ef ciency is a very im ortant as ect in an Internet-of-Things scenario in which smart objects have to reserve the battery cons m tion Obvio sly in this conte t what we have to minimi e the n mber of contacts er object rovided that the ef ciency of the network also in terms of cohesion is reserved

By considering *degree centralization* o r network achieves slightly better res lts allowing s to concl de that it is more incline to have information ac c m lation oints that can be sed as seeds to start the information ro agation Mislove et al 2007 Moreover better res lts are achieved for *component ratio* and *connectedness* These arameters meas re the cohesion of the network and show s that o r network has a single connected com onent so all the nodes are reachable and that the connectivity is higher than the classical network The latter ro erty means that the e ected n mber of ho s to reach a given target is red ced in o r network w r t the classical one ence also for the *compactness* and *fragmentation* oint of view we can concl de that the strategy based on assortativity chooses only not red ndant links that allow a f ll connectivity We observe that this has not a cost in terms of network resilience Indeed according to the de nition of fragmentation as it is 0 676 vs 0 776 of the classical network we obtain a network that is more resilient

In s mmary the obtained res lts allow s to state that the a roach based on interest assortativity has been able to b ild a network showing better ef ciency in terms of both node reachability and cohesion level n im ortant achievement is that nodes e hibit a red ced average degree w r t the classical network This as ect has a dee im act on the traf c level and d lication in broadcast comm nications which is

Table 1 Statistics of o r dataset

	ro imity-based	O r roach
Avg Degree	12 017	10 075
Density	0 101	0 0 5
Deg Centralization	0 265	0 273
Component Ratio	0 52	1
Connectedness	0 224	0 324
Compactness	0 162	0 1 0
Fragmentation	0 776	0 676

clearly red ced in o r network

4 RELATED WORK

In recent years IoT has gained m ch attention from researchers and ractitioners beca se this new scenario is o ening new o ort nities for a large n mber of novel a lications ia et al 2012 Leavell and Coo er 2016 o et 2011 t ori et al 2010 One of the most challenging iss e is how to b ild the network of objects to access services and data in this new scenario hang et al 2011 Some ro osals are resented in dwards 2006 ort em et al 2010 Wang et al 2010 Ya et al 200 ara et al 2014 In artic lar in ort em et al 2010 smart items erceive and instr ct their environment by ca t ring and inter reting ser actions to analy e their observations and to comm nicate with other objects and the Internet Wang et al 2010 resents a search engine sef l to nd s itable smart devices The retrieval is erformed thanks to the descri tion contained within the objects themselves or other ser de ned information ser can ery the engine to nd a artic lar mobile object or a list of objects that t the descri tion lso the system resented in Ya et al 200 allows h mans to search for and locate smart things as needed altho gh it is based on a hierarchical architect re consisting of tags s bstations and basestations The architect re resented in ara et al 2014 e loits social tools to erform node discovery It allows sers to register their own sensors into a common infrastr ct re and then discover the available reso rces thro gh mobile O r ro osal strongly leverages on interest assortativity B ccaf rri et al 2016a The conce t of assortativity was rstly ro osed by Newman 2002 in terms of degree-degree assortativity Therein the a thors demonstrated that social networks are often assortatively mi ed in the sense that the nodes in the network having many relationshi s tend to be connected to other nodes highly connected themselves Starting from Newman 2002 f rther st dies concerning social network assortativity have been ro osed s ch as Goh et al 2003 Newman and ark 2003 Catan aro et al 2004 Wilson et al 200 In artic lar Goh et al 2003 st dies the relationshi between assortativity and betweenness centrality correlation for scale-free networks Newman and ark 2003 analy es the relation between assortativity and cl stering in social comm nities discovering that these comm nities are characteri ed by both high levels of cl stering and assortative mi ing By contrast Catan aro et al 2004 com ares different ty e of networks e g technological biological and social networks showing that only social networks are ty ically assortative with res ect to the degree whereas the others a ear in general to be disassortative Wilson et al 200 models interaction relationshi s among sers thro gh an interaction gra h

5 CONCLUSION

Internet of Things aradigm is an e tremely romising scenario that o ens new challenging ers ectives in terms of interaction between h mans and machines In this conte t a lot of im rovements can be done or instance one of the most critical iss es is how to choose the links among objects in order to b ild an ef cient network

In this a er we resent a new selection criterion that im roves the classical ro imity a roaches To do this we relied on the res lts resented by B caf rri et al 2016a This work shows that Twitter is highly assortative in sers interests i e sers behave niformly w r t different to ics and it resents a new social network metric called interest assortativity

This osition a er shows a rst e erimental evidence of this res lt by ill strating that o r a roach erforms better than the classical strategies Indeed o r selection criterion allowed s to ick only not red ndant links This res lt is advantageo s in terms of network connectivity and battery cons m tion which are two cr cial as ects for smart devices This enco rages s to more dee ly analy e this iss e in the ne t f t re also by testing some different ways to combine direct and indirect knowledge

REFERENCES

2016 Gra hofThings *http://github.com/GraphAlchemist/GraphofThings*

2016 Neo4 World s leading gra h database *http://neo4j.com/*

2016 CIN T Software *http://sites.google.com/site/ucinetsoftware* t ori L Iera and Morabito G 2010 The internet of things s rvey *Computer networks* 54 15 27 7 2 05

B ccaf rri La G Nicola o S and Nocera 2015a Com aring twitter and facebook ser behavior rivacy and other as ects *Computers in Human Behavior* 52 7 5

B ccaf rri La G Nicola o S and Nocera 2016a Interest assortativity in twitter In *Proceedings of the 13th International Conference on Web Information Systems and Technologies (WEBIST)* W - BIST

B ccaf rri La G Nicola o S and Nocera 2016b model to s ort design and develo ment of m lti le-social-network a lications *Information Sciences* 331 11

B ccaf rri La G and Nocera 2015b New orm of ssortativity in Online Social Networks *International Journal of Human-Computer Studies* 0 56 65

B ccaf rri La G Nocera and rsino D 2015c Discovering Missing Me dges across Social Networks *Information Sciences* 31 1 37

Catan aro M Caldarelli G and ietronero L 2004 Social network growth with assortative mi ing *Physica A: Statistical Mechanics and its Applications* 33 1 11 124

dwards W 2006 Discovery systems in bi ito s com ting *IEEE Pervasive Computing* 5 2 70 77

vangelos Nikolaos D T and nthony C B 2011 Integrating r ds and smart objects into a ni edinternet of things architect re *Advances in Internet of Things* 2011

Goh Oh ahng B and im D 2003 Betweenness centrality correlation in social networks *Physical Review E* 67 1 017101

ara Lo e ernande D Castillo amora M and Skarmeta 2014 Mobile digcovery discovering and interacting with the world thro gh the internet of things *Personal and ubiquitous computing* 1 2 323 33

o et 2011 Internet of things In *Real-time systems* ages 307 323 S ringer

ort em G awsar S ndramoorthy and itton D 2010 Smart objects as b ilding blocks for the internet of things *IEEE Internet Computing* 14 1 44 51

Leavell and Coo er D 2016 The internet of things Strategic considerations for bankers *Journal of Digital Banking* 1 1 22 32

Mislove Marcon M G mmadi Dr schel and Bhattacharjee B 2007 Meas rement and analysis of online social networks In *Proceedings of the 7th ACM SIGCOMM conference on Internet measurement* ages 2 42 CM

Newman M and ark 2003 Why social networks are different from other ty es of networks *Physical Review E* 6 3 036122

Newman M 2002 ssortative mi ing in networks *Physical review letters* 20 20 701

nion I T 2005 The Internet of Things *7th Edition, International Telecommunication Union Internet Reports*

Wang Tan C C and Li 2010 Snoogle search engine for ervasive environments *IEEE Transactions on Parallel and Distributed Systems* 21 11 1202

Wilson C Boe B Sala ttaswamy and hao B 200 ser interactions in social networks and their im lications In *Proc. of the ACM European Conference on Computer systems (EuroSys'09)* ages 205 21 N remberg Germany CM

ia Yang L T Wang L and inel 2012 Internet of things *International Journal of Communication Systems* 25 1101

Ya - Srinivasan and Motani M 200 Ma Wide area h man-centric search of the hysical world *ACM Transactions on Sensor Networks (TOSN)* 4 4 26

hang D Yang L T and ang 2011 Searching in internet of things ision and challenges In *2011 IEEE Ninth International Symposium on Parallel and Distributed Processing with Applications* ages 201 206 I