ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization) Vol.2, Special Issue 1, March 2014

Proceedings of International Conference On Global Innovations In Computing Technology (ICGICT'14)

Organized by

Department of CSE, JayShriram Group of Institutions, Tirupur, Tamilnadu, India on 6th & 7th March 2014

Intelligent network stabilization of dynamical systems using topological condition

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ABSTRACT-Stabilizing a linear system over a wireless network using a simple intelligent-network computation method. Specifically, using architecture called the "Wireless Control Network" (WCN), where each wireless node maintains a state, and periodically updates it as a linear combination of neigh boring plant outputs and node states. This architecture has previously low computational overhead and beneficial scheduling and compositionality properties. Using some characterize fundamental topological conditions to allow stabilization using such a scheme. This, WCN scheme causes the network to act as a linear dynamical system, and analyze the coupling between the plant's dynamics and the dynamics of the network. That stabilizing control inputs can be computed intelligent-network if the vertex connectivity network is larger than the geometric multiplicity of any unstable eigen value of the plant. This Min-cut condition required in classical information dissemination problems. Topological conditions also using in wired(or point- to -point) network that employs network coding in a communication mechanism between the plant's sensors and decentralized controllers at the actuators.

KEYWORDS- Networked control systems, decentralized control, wireless sensor networks, structured systems, in-network control, network coding, cooperative control

I. INTRODUCTION

The sensor and actuator technologies, availability of powerful but inexpensive embedded computing and introducing new multi-hop wireless network control over wireless networks is becoming a disruptive technology .Interconnections between the plant sensors, controllers and actuators can be replaced by wireless multi-hop mesh networks, yielding cost and space savings for the plant operator. Delays may be introduced if a multi-hop wireless network is used to route information between the plant sensors, actuators and controllers. Transmissions in the network must be scheduled carefully to avoid packet Dropouts due to collisions between neigh boring nodes. The convention of having one or more dedicated controllers or state estimators located in the system, and study the stability of the closed loop system assuming that the sensor estimator and/or controller-actuator communication channels are unreliable.

For this standard architecture, the dedicated controllers a routing requirement along one or more fixed paths through the network, along with strict end-to-end delay constrains. And new control loops are added at run-time. Communication and they will computation schedules every time a new loop will beaded to the system. To avoid this complexity, a new loop does not affect the functioning of existing control loops. In order to do so, one requires an alternative to the routing-based approaches currently employed for control over wireless networks. The widespread availability of low-cost wireless networking technology. Wireless communications into the feedback loop also presents delays due to multi-hop routing or packet dropouts due to transmission collisions can be detrimental to the goal of maintaining stability of the system .distributed algorithm for the resource-constrained wireless nodes to follow so that the computation of the control law is done collectively by the network.

Develop a method to incorporate structural analysis (which abstracts away all numerical system parameters) into the design of a control network for a numerically specified plant is stabilizable and detectable from all of its inputs and outputs taken together, and as long as the wireless network provides paths from certain plant sensors to certain other plant actuators choice of coefficients in the linear iterative strategy employed by the network nodes, The results is that stabilization is possible despite the length of the paths between the sensors and actuators, as long as compensators of sufficiently large order are allowed at the actuators.

The decentralized fixed modes of a linear dynamical system are Eigen values of the plant that cannot be moved by static output feedback. To handle arbitrary feedback patterns, and to enable a graph-theoretic analysis of the problem. The WCN is a structured controller. It can be shown that in this case there is no stabilizing configuration for the WCN when each node maintains a scalar state. The set is connected to the network. In other words, considered only the interconnections between the plant state variables, but did not consider the numerical values of those interconnections. This allowed us to characterize WCN properties that would guarantee stabilization of almost any plant having a certain structure. WCN to satisfy in order to stabilize both structured and numerically specified plants.

II. WIRELESS CONTROL NETWORK

The standard "sensor, channel, controller/estimator channel , actuator" are the architecture a distributed algorithm for the (resource constrained) wireless nodes to follow so that the network itself acts as a controller for the plan network of wireless nodes is deployed in nodes having access to the sensor measurements (outputs) of the plant, and some nodes placed within the listening range of the plant's actuators ,that each node is capable of maintaining only a limited internal state, where each node periodically updates its state to be a linear combination of the states of the node in immediate neighbourhood. The network's topology, The devised a design-time procedure to derive the coefficients of the linear combinations for each node and actuator to apply in order to stabilize the plant.

To model resource constrained nodes, we assumed that each node is capable of maintaining only a limited internal state. We then presented a distributed algorithm in the form of a linear iterative strategy for each node to follow, where each node periodically updates its state to be a linear combination of the states of the nodes in its immediate neighborhood. The actuators of the plant also apply linear combinations of the states of the nodes in their neighborhood. Given a linear plant model and the network's topology, we devised a design-time procedure to derive the coefficients of the linear combinations for each node and actuator to apply in order to stabilize the plant. We showed that our method could also handle a sufficiently low rate of packet dropouts in the network to maintain mean square stability. We referred to this paradig , where the computation of the control law is done in-network(i.e., in a distributed fashion by the wireless nodes), as a Wireless Control Network (WCN). The scheme has several. The network clearly satisfied the condition .In general, there will be many different reduced networks obtainable from a given network depending on the order in which the branches are chosen. If a satisfactory flow pattern can be found for a reduced network, it is clear that the same flow pattern will be satisfactory in the original network, since both the Kirchhoff condition and the capacity limitation will be satisfied.

The minimum cut-set flow cannot be exceeded, consider any given flow pattern and a minimum valued cut-set C. Take the algebraic sum X of flows from left to right across this cut-set. This is clearly less than or equal to the value V of the cut-set, since the latter would result if all paths from left to right in C were carrying full capacity, and those in the reverse direction were carrying zero. Now add to S the sum of the algebraic flows into all nodes in the right-hand group for the cutest C. This sum is zero because of the Kirchhoff law constraint at each node.

III. MULTI-HOP WCN

The start our analysis by initially disregarding the effects of the actuators on the plant; i.e., we assume that at each time-step the plant actuators do not use transmissions from the nodes in the set VA to actuate the plant (via (5)). This allows us to consider the plant £ = (A;B;C) and the WCN together as a linear system where the outputs of the plant are injected Into the WCN If we view the transmissions of the nodes in VA as the output of the £ system can be specified as:

$$\hat{x}[k+1] = \begin{bmatrix} x[k+1] \\ z[k+1] \end{bmatrix} = \underbrace{\begin{bmatrix} A & 0 \\ HC & W \end{bmatrix}}_{\tilde{A}} \begin{bmatrix} x[k] \\ z[k] \end{bmatrix} + \underbrace{\begin{bmatrix} B \\ 0 \end{bmatrix}}_{\tilde{B}} u[k],$$

$$\hat{y}[k] = \underbrace{\begin{bmatrix} 0 & E_{\mathcal{V}_A} \end{bmatrix}}_{\tilde{C}} \begin{bmatrix} x[k] \\ z[k] \end{bmatrix}.$$

Here EV_A= [ei1, ei2….eit]. Recall that X is the set of state vertices (corresponding to the states of the plant), U is the set of p input vertices (corresponding to the actuators), and V is the set of vertices corresponding to the network nodes. The set EA represents the edges between state vertices (given by the matrix A), and EB represents edges from the plant inputs to the states(given by the matrix B). The set E represents the topology of the network, and the set EO captures how the state vertices influence the vertices in the wireless network. Specifically, the states of the plant affect the outputs of the plant (via the edge set EC), and each plant output connects to one or more nodes (via the edge set E out defined in (2)). As the output vertices simply pass the information about the state vertices through to the wireless network, we can remove the output vertices from the representation and introduce connections directly from the state vertices to the wireless vertices as follows:

EO = f(xi; vj) 2 X _ VSj9yk 2 Y; (xi; yk) 2 EC; (yk; vj) 2 Eoutg:

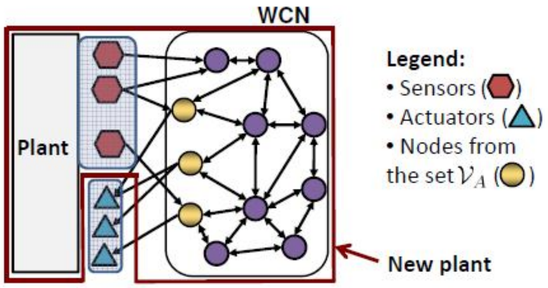

Fig 1.1 system architecture

To model resource constrained nodes, assumed that each node is capable of maintaining only a limited internal state.Then presented a distributed algorithm in the form of a linear iterative strategy for each node to follow, where each node periodically updates its state to be a linear combination of the states of the nodes in its immediate neighbourhood. The actuators of the plant also apply linear combinations of the states of the nodes in their neighbourhood. Given a linear plant model and the network's topology, Devised a design-time procedure to derive the coefficients of the linear combinations for each node and actuator to apply in order to stabilize the plant. The method could also handle a sufficiently low rate of packet dropouts in the network to maintain mean square stability. Referred to this paradigm, where the computation of the control law is done in-network as a Wireless Control Network (WCN). The scheme has several benefits, including easy scheduling of wireless transmissions, compositional design, and the ability to handle geographically separated sensors and actuators. Then illustrated the use of the WCN in industrial process control applications

Advantage of the system architecture for the wireless network system model in the model.

1. WCN in industrial process control applications
2. Less time should be taken and cost will be low saving place
3. Easy scheduling of wireless transmissions

A fixed mode will be introduced with Each wcn state vertex zi that does not belong to a strong component in the graph g~_in= (v~_; e~_ [ein) with an edge from ein (this might happen if the network is disconnected).however, by setting to zero all the weights associated with the links outgoing from zi, this wcn state vertex is effectively. removed from the network. In this case, due to the state vertex zi the system has a structured fixed mode in the origin. Thus, In both cases the closed-loop system does not have structured fixed-modes outside of zero, meaning that almost every system with this structure will be stabilizable using the wcn.

For instance, delays may be introduced if a multi-hop wireless network is used to route Furthermore, transmissions in the network must be scheduled carefully information between the plant sensors, actuators and controllers. T avoid packet dropouts due to collisions between neighbouring nodes. These issues can be detrimental to the goal of maintaining stability of the closed loop system if not explicitly accounted for, and substantial research has been devoted to understanding the performance limitations in such settings These works typically adopt the convention of having one or more dedicated controllers or state estimators located in the system, and study the stability of the closed loop system assuming that the sensor estimator and/or controller-actuator communication channels are unreliable (dropping packets with a certain probability, For this standard architecture the use of dedicated controllers imposes a routing requirement along one or more fixed paths through the network, along with strict end-to-end delay constraints to ensure stability.

IV. EXTENSIONS TO POINT-TO-POINT NETWORKS

Wireless Control Network our analysis can be extended in a straightforward manner for control over networks with wired communication links. We consider the problem of network synthesis for the case where network coding over point-to-point communication links is use. Our goal is to provide topological conditions that guarantee that there exist linear dynamical controllers (at the actuators) that can stabilize the plant. We focus on two scenarios. We start with the case when the network delay (over each link in the network) is equal to the sampling period of the plant. We then investigate the case when an idealized, delay-free network is used. It is worth noting that this scenario can be used to model closed-loop systems where the speed of the network is much higher than the sampling period of the plant.

Suppose that Gc = (Vc;Ec [Y1:p [U1:m) is a network with point-to-point links, where Y1:p = [p i=1Yi represents the links coming into the network from the plant's sensors, andU1:m = [mj=1Uj represents the set of links coming out of the network into the plant's actuators. As is standard in linear network coding, the information sent on each outgoing edge from a given network node is a linear combination of information carried on the edges entering that node. Note that in the wired communication model, the linear combinations on each outgoing edge are allowed to be different. As shown in [12],from the graph Gc we can obtain the (unique) directed labeled line graph B = (VB; EB), where VB = Ec [Y1:p [U1:m,and for all ei; ej 2 VB, (ei; ej) 2 EB if and only if there exist v1; v2; v3 2 Vc such that ei = (v1; v2) and ej = (v2; v3)(i.e., head(e1) = tail(e2)). Each link (ei; ej) 2 EB is labeled With the coefficient (i.e., weight) assigned to the information received over edge ei in the linear combination that is used to produce information over ej .An illustration of this procedure is shown in where the labeled line graph is given for the network from Note that each link in the initial graph corresponds to a unique vertex in the labeled line graph .If each link in the initial network introduces a fixed communication.

Similar results can be obtained in the case with delay-free communication networks, where the information injected in the network by the plant's sensors is expected to be instantaneously available at the actuators. In this case, as described in [12], for the directed labeled graph of the initial network we can define W – the adjacency matrix of the labeled graph .Here, wij is the weight assigned to the edge ei in the linear combination used to derive ej (if head(ei) 6= tail(ej) then wij = 0).9 Using the matrix W, as in [12] it can be shown that for any set I _ M, EF (W ☐ I)☐1H is the transfer matrix of the network, from the input edges to the output edges10 This is equal to the WCN transfer function, evaluated at _ = 1, which is used in the proof of Theorem 8. Therefore, by using the same approach from the proof of Theorem 8, we can formulate theorem equivalent This means that, even for delay-free networks that use network coding over point-to-point links, Theorem 10specifies sufficient conditions for the existence of network coding parameters for which the plant can be stabilized via controllers at the actuators.

The conditions for a given system to not have structural fixed modes when controlled using a WCN, where each node in the network maintains only a scalar state, and the actuator nodes maintain vector states. Start analysis by initially disregarding the effects of the actuators on the plant; i.e., assume that at each time-step the plant actuators do not use transmissions from the nodes in the set VA to actuate the plant. In decentralized control systems, a set of non-interacting local controllers is used to control a dynamical system (plant); each of the controllers generates the appropriate plant inputs by observing only a subset of the plant's outputs. Due to these limitations imposed on each of the local controllers, it is possible that even a controllable and observable system cannot be stabilized with the aforementioned setup. As shown in the problem of decentralized control can be formulated as a static output feedback control problem, where the feedback matrix potentially has some sparsity constraints. Furthermore, introduced the notion of fixed modes to derive conditions for the existence of a stabilizing set of decentralized controllers. The concept of fixed modes was generalized in to handle arbitrary feedback patterns, and to enable a graph-theoretic analysis of the problem.

V. CONCLUSION

The problem of stabilizing a given dynamical system over a network. In contrast to traditional approaches that treat the network purely as a routing mechanism (delivering sensor measurements to controllers, and control inputs to actuators), Propose a fundamentally different approach that relies on inducing carefully chosen dynamics on the network (via the form of a simple distributed algorithm), and using those dynamics to stabilize the plant. This approach does away with end-to-end routing entirely, and only requires that nodes transmit information to their nearest neighbours at each time-step. Toprovided topological conditions on the network that allow the system to be stabilized in this manner. Specifically, Showed that if the network is sufficiently well connected, each node and actuator can use a linear iterative strategy with appropriately chosen weights to stabilize the plant; furthermore, the connectivity required is determined by the dynamics of the plant, rather than the number of source nodes (as in traditional information transmission scenarios). The approach also extends in a straightforward manner to wired (point-to-point) networks via a standard graph transformation.

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