The International Journal Research Publication's ISSN:2251 1563
Research Journal of Science & IT Management

Energy Enhancement in Wireless SensorNetworks through Distributed Fibre Sensor

Mr Deepak Choudhary,
Associate Professor in Electronics and Communication Department ABES Engineering. College Ghaziabad, UP India
&
Mr Sanjay Mahawar,
Associate Professor in Electronics and Communication Department ABES Engg. College Ghaziabad, UP India

Abstract—Based on the protocol—low-energy adaptive clusteringhierarchy (LEACH), we investigate an improved energy-efficientcommunication protocol for wireless sensor networks(WSNs) in the presence of distributed optical fiber sensor (DFS)links located at the centre of WSN fields. Network performancesin terms of lifetime of nodes are simulated for the cases that twoWSNs can or cannot communicate with each other. The lifetimeof such sensor network with rectangular topology is furtherinvestigated.

Index Terms—Distributed optical fiber sensor, low-energy adaptive clustering hierarchy (LEACH), protocol, sensor network, wireless sensor network.

I. INTRODUCTION

WIRELESS SENSOR NETWORK (WSN) has attractedconsiderable attentions during the last few years due tocharacteristics such as feasibility of rapid deployment, self-organization(different from ad hoc networks though) and fault
tolerance, as well as rapid development of wireless communications and integrated electronics [1]. Such networks are constructedby randomly but densely scattered tiny sensor nodes[Fig. 1(a)]. As sensor nodes are prone to failures and the networktopology changes very frequently, different protocols havebeen proposed to save the overall energy dissipation in WSNs [2]–[5]. Among them, Low-Energy-Adaptive-Clustering-Hierarchy(LEACH), first proposed by researchers from MassachusettsInstitute of Technology [5], is considered to be one of themost effective protocols in terms of energy efficiency [6], [7].

On the other hand, distributed fiber sensors (DFS) have been intensively studied or even deployed for analyzing loss, external pressure, temperature or birefringence distribution along the fiber link, ranging from hundreds of meters to tens of kilometers [8]–[13]. Mechanisms include Rayleigh, Brillouin,or Raman scattering or polarization effects, through either timeor frequency-domain analysis. Compared with conventionalsensors including wireless ones, optical fiber sensors haveintrinsic advantages such as high sensitivity, the immunityto electromagnetic interference (EMI), superior endurance inharsh environments and much longer lifetime.

Apparently it would be highly desirable to have integratedsensor networks that can take advantages of both WSNs andoptical sensor networks (OSNs). Such hybrid sensor networkscan find major applications including monitoring inaccessibleterrains (military, high-voltage electricity facilities, etc.), long term observation of earthquake activity and large area environmentalcontrol with tunnels, and so on. Especially under harshenvironments (e.g., high humidity, strong EMI, etc.),OSN has tobe deployed. So far, hybrid sensor networks have been studiedas well [14]–[16], while optical sensors in these networks aregenerally point-like (e.g., fiber-Bragg-grating based), and such nodes can be regarded as normal WSN nodes after optical towireless signal conversion.

In this paper, we investigate an infrastructure of a sensor networkthat is composed of a DFS link and two separated WSNs,as shown in Fig. 1(b). The DFS link is located at the center of the whole sensor field and can cover a certain area. The twoWSN fields are filled with randomly scattered nodes as usual.These nodes can or cannot communicate with each other dependingon the application requirements. Unlike simple WSNs,since the DFS has to be powered on for data processing (as an activesensor "link" without energy restriction), we use one end ofthe DFS as the sink or the base station (BS) for all WSN nodes.Although the performance (lifetime) of the DFS may have to beconsidered as well, here we assume that the lifetime of such asensor network is mainly determined by the WSN.We speciallyinvestigate an improved energy efficient communication protocol, optical LEACH (O-LEACH), based on the WSN LEACHprotocol. The performance of the whole sensor network is simulatedunder different scenarios. We find that such clusteringbased protocol still exhibits good energy efficiency in the sensornetwork, especially when two WSNs are not reachable to eachother. In addition, as the DFS may cover a long rectangular area (up to tens of kilometers), O-LEACH protocol is used to investigatethe lifetime of the hybrid sensor network with rectangulartopology by dividing and linking a series of WSNs around theDFS.

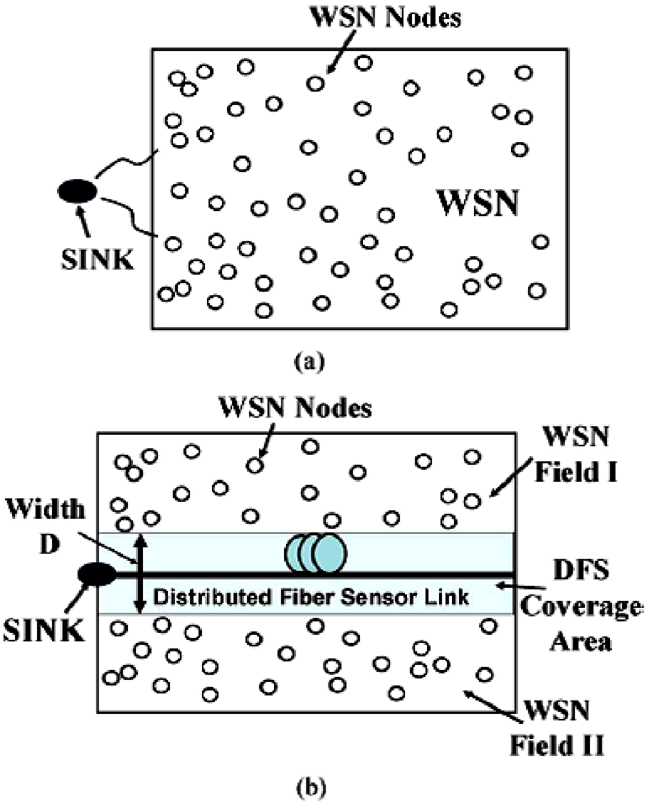


Fig. 1. (a) Illustration of aWSN with randomly scattered nodes (sink node: no.Energy restriction; WSN nodes: with energy restriction); (b) Sensor field consistingof a DFS link and two WSN fields (I and II), the sink node is located atone end of the DFS and the width of the DFS coverage area is D.

II. O-LEACH PROTOCOL

As only nodes of two WSNs are energy or power limited,the protocol is mainly dealing with these nodes, starting fromrandom node positioning outside the DFS coverage area, whileinside the phenomenon. As the LEACH protocol is one of mostpopular WSN protocols, here we only give a brief introductionabout that and more details could be found in [1] and [5].LEACHis a cluster-based protocol. In the protocol, the sensornodes in the network are divided into a number of clusters,the nodes organize themselves into preferred local clusters, asensor node is selected randomly as the cluster head (CH) ineach cluster and this role is rotated to evenly distribute the energyload among nodes of the network. The CH nodes compressdata arriving from nodes that belong to the respective cluster,and send an aggregated packet to the BS in order to furtherreduce the amount of information that must be transmitted tothe BS, thus reducing energy dissipation and enhancing systemlifetime. After a given interval of time, randomized rotation ofthe role of CH is conducted to maximize the uniformity of energydissipation of the network. Sensors elect themselves to belocal cluster heads at

any time with a certain probability. Generallyonly % of nodes needs to act as CHs based on simulationresults. LEACH uses a TDMA/CDMA MAC to reduceinter-cluster and intra-cluster collisions. As data collection is centralizedand performed periodically, this protocol is most appropriatewhen there is a need for constant monitoring by the sensornetwork.
The flowchart of the O-LEACH protocol is shown in Fig. 2.As the operation of the standard LEACH protocol is separatedinto the setup phase and the steady phase, we also separatethe O-LEACH operation into two phases, and the steadyphase is as same as the LEACH one [5]. During the setupphase, the selection of the cluster-head follows the similarcriteria as LEACH, but there are two major differences betweenO-LEACH and LEACH: (i) nodes of WSNs cannot be deployedin the DFS coverage area (first check) and (ii) the cluster-headand the node should be within the same WSN field if twoWSNs cannot communicate with each other (i.e., checkingin the flowchart).
For most applications, it would be better to assume that twoWSN fields are isolated due to the following reasons: (i) saving information transfer energy since longer data transfer distanceover the DFS terrain ends with higher energy consumptionand (ii) wireless communication over the DFS area is not evenallowed for some applications. However, we simulate the casethat nodes inside different WSN fields can communicate witheach other as well for reference. From the flow chart of theO-LEACH protocol, we have to admit the fact that the proposedprotocol is only a fairly incremental modification to the originalLEACH. The main point is to initiate the study about hybridsensor networks with intriguing results.

III. SIMULATION RESULTS

Based on the O-LEACH protocol, we simulate the networkperformance in terms of the node lifetime. In our simulationmodel: 1) most of parameters (e.g., probability of a node tobecome cluster head, data packet length, control packet length,etc.) are as same as other LEACH-based simulation models(listed in Table I) [5]–[7]; 2) the position of the sink in theLEACH model can be put in different places, while in ourLEACH and O-LEACH ones, we put the sink of all the cases tothe same position, i.e., in the middle of one edge of the sensorfield (i.e., the centre of one end of the DFS), although later infor the rectangular topology, we add a series of sinks to covermuch longer distances with more evenly distributed energyconsumption; 3) as the network energy dissipation is a totallystatistical behaviour due to the random distribution of WSNnodes, we simulate every case for 1000 independent iterations(it takes days to get such statistical results); and 4) as the ONS

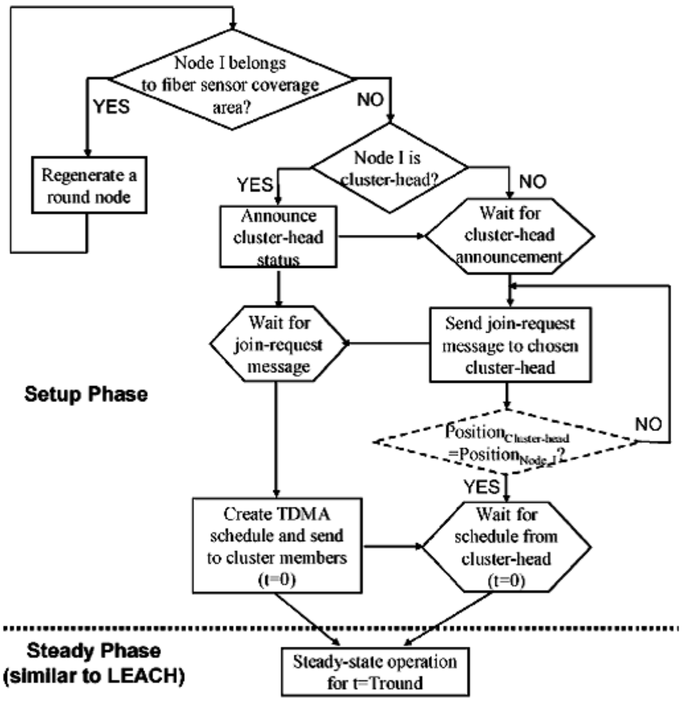


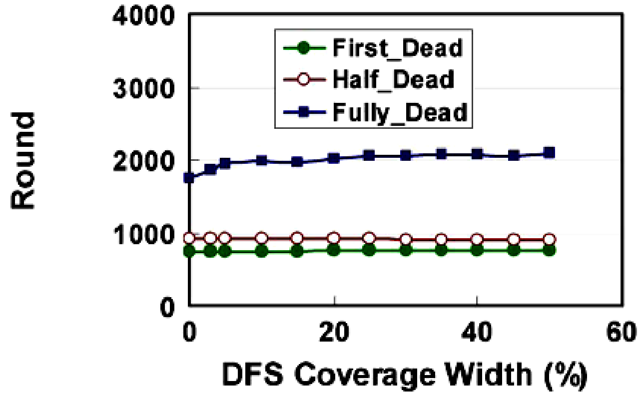
Fig. 2.Flowchart of the O-LEACH protocol.

TABLE I

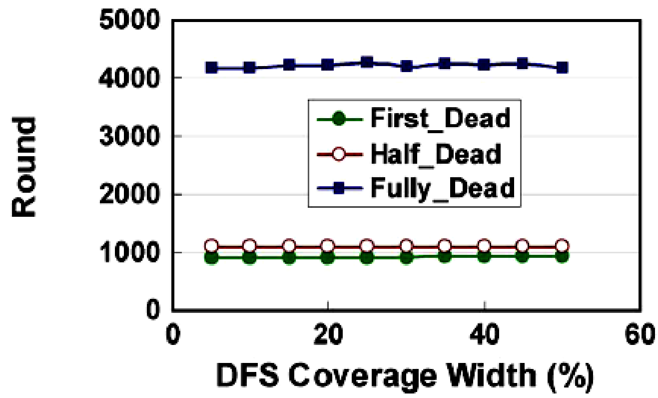
PARAMETERS USED IN SIMULATION OF O-LEACH [5]

Dimension of sensor field (a.u.)	100x100
Probability to be cluster head	0.05
Data packet length	4000
Control packet length	200
Initial energy (J)	0.5
Energy dissipation of one Tx (J)	5e-8
Energy dissipation of one Rx (J)	5e-8
Energy loss - free space (J)	1e-11
Energy loss - multipass fading (J)	1.3e-15
Data aggregation energy (J)	5e-9

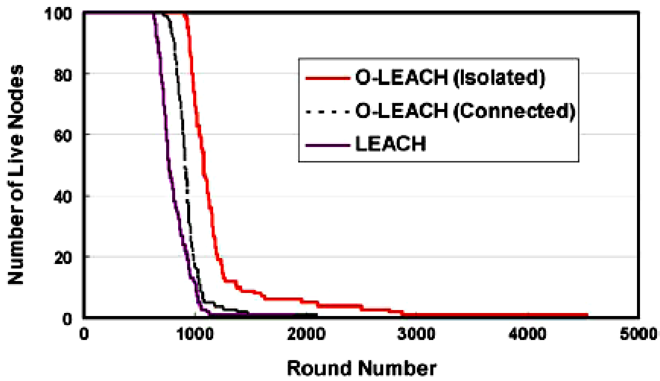
(DFS) is totally active (i.e., no energy constraint), the lifetime of the DFS is not considered.First, we compare the network performance in terms of thelifetime. Three cases are simulated: original LEACH withoutDFS; O-LEACH with varying the width of DFS coverage area(D) that two WSNs either can or cannot communicate with eachother. As people use different parameters to evaluate the lifetime,i.e., the round number corresponding to the appearance ofthe first dead node, half of dead nodes or the last survival node(called as "first-dead," "half-dead," and "fully-dead" in the followingpart of the paper), we obtain all three parameters andfind that network improvement may end with quite different resultsthrough these parameters. A node is considered to be deadif the remaining energy is zero [5], although reduced communicationreliability may happen during the energy depletion. Notethat in most practical applications, the DFS coverage is very specificand cannot be freely varied. While sometimes parallel DFSlinks may be deployed to cover more broad areas, therefore, theDFS coverage width is varied in our simulation for the purposeof comparison and possible reference.



(a)



(b)



(c)

Fig. 3. Simulation results of network performance in terms of lifetime (roundnumber) using O-LEACH protocol. (a) TwoWSNs can communicate with eachother. (b) Two WSNs are isolated. (c) Typical lifetime evolution curves.

For the LEACH case, we obtain the average round numbercorresponding to "first-dead," "half-dead," and "fully-dead" are731, 915, and 1741, respectively. Fig. 3(a) and (b) show the averagelifetime evaluated by three "-dead" parameters for situationsthat the two WSNs can and cannot communicate witheach other as we vary the value of D (from 5 to 50).We can seethat: 1) The network performance in terms of lifetime keeps almostconstant regardless the width of DFS coverage. 2) In thecase that two WSNs cannot communicate with each other, nodescan save energy on broadcasting over smaller area (i.e., shorterdistance), therefore, the average lifetime corresponding to either"first-dead" or "half-dead" is improved % comparedto the case that two WSNs are connected (the average roundnumber from 731 to 903 and from 915 to 1086 for "first-dead"and "half-dead", respectively), while the last node's lifetime("fully-dead") is more than doubled. 3) Compared to the conventionalLEACH protocol, the improvement of O-LEACH iftwo WSNs can communicate with each other is very limited (% and % in terms of "first-dead" and "fully-dead," respectively.In fact, such improvement is simply converged tothe original LEACH case if we further reduce the coverage percentage,i.e., %). Therefore, it is expected and mostly requiredfor such hybrid sensor networks to employ O-LEACHwith two WSNs isolated. Furthermore, typical lifetime evolutionsare compared as well in Fig. 3(c), where D equals 20.These curves are specially chosen from thousands of simulatediterations with performance close to average ones. Results ofLEACH protocol are also included.A legitimate question for above network model is how closeto the reality of the hybrid sensor network in terms of the coverageof DFS and WSN. As mentioned in the introduction section,the distance of typical DFS link can vary from hundredsof meters to tens of kilometers, while the coverage diameter ofWSN node is tens of meters. Therefore, it would be interestingto look into the case that the length of DFS link increases andthe number of WSN nodes increases proportionally (to keep theapproximate density).

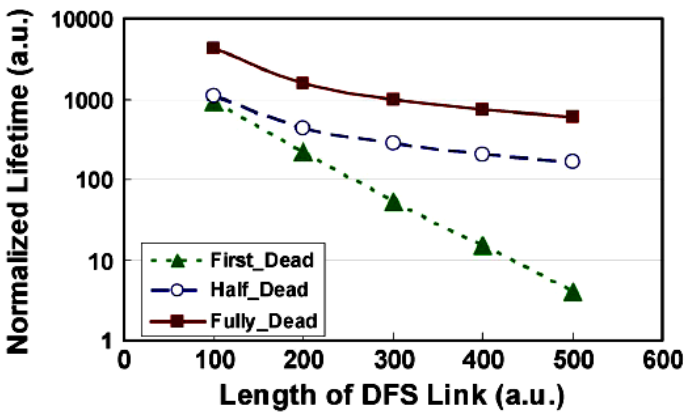


Fig. 4. Normalized lifetime as we increase the length of DFS link (number ofWSN nodes are increased proportionally, the widths of the DFS coverage areaand the whole sensor field are fixed).

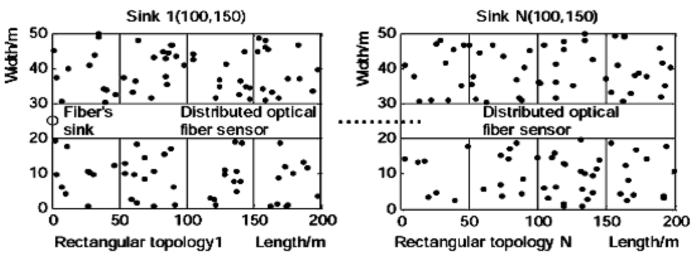


Fig. 5. The topology incorporating distributed optical fiber sensors.

To keep straightforward but simple, we fix the width of thewhole sensor field to 100 and the coverage percentage of DFSto 20% (i.e.,Dequals to 20). Also, we only consider the case thattwo WSNs are isolated. Fig. 4 illustrates the trend of normalizedlifetime performance with increasing link length of DFS. Thenormalization is done using the ratio of the "-dead" parameterto the total node number. It is obvious that 100 is the optimumnumber for WSN nodes with parameters listed in Table I. As thelength of the DFS link increases, the lifetime reduces dramatically,especially the "first-dead" parameter. More wireless sinksare required for longer DFS links, and the performance evaluationof various optical wireless sensor network topologies areof great interests. More practically, the number of base stations(sinks) should be increased (or linked into series) to sustain thelong rectangular sensor field.Therefore, as a more general topology, Fig. 5 shows such hybridsensor networks that have potential to cover much morebroad areas under certain guidelines: 1) cascade of multiplerectangular regions in which the base station location of WSNsensor node is (100, 150) and 2) the DFS is located in the monitorarea with massive volume of data, harsh environment, andpoor security (located in the middle of the rectangular regionfor this paper) to link the rectangular region and the locationof fiber's base station is (0, 25). The DFS can cover a certainarea as previously discussed, for example 10 m (vertical axis),to monitor the required (e.g., temperature, strain, etc.) informationwithin the coverage area, and give the data back to the fiberbase station (still located at the center of one end of the DFS andwith no need to worry about its power consumption).For more general topology of the hybrid OSN (DFS) andWSN network, we modify the O-LEACH algorithm and simulatea m rectangular sensor network region that is dividedinto four small regions (i.e., in Fig. 5). In the totalarea, we randomly scatter 100 nodes, e.g., the number of nodesin each region is 21, 29, 23, and 27, respectively. The DFS islocated in the middle of the total rectangular region as usual.We assume that the nodes in the upper and the lower part of theoptical region can communicate with each other, and the simulationresults are shown in Fig. 6.We can see from Fig. 6 that the round numbers of the firstdeadnode in the four regions are 663, 805, 779, and 698, respectively.The first 20% of nodes die slowly, but the remainingones die rapidly in the total region. The results further demonstratethat the hybrid sensor network incorporating DFS with theO-LEACHprotocol can evenly distribute the energy load amongnodes, therefore prolong the overall lifetime of the network.

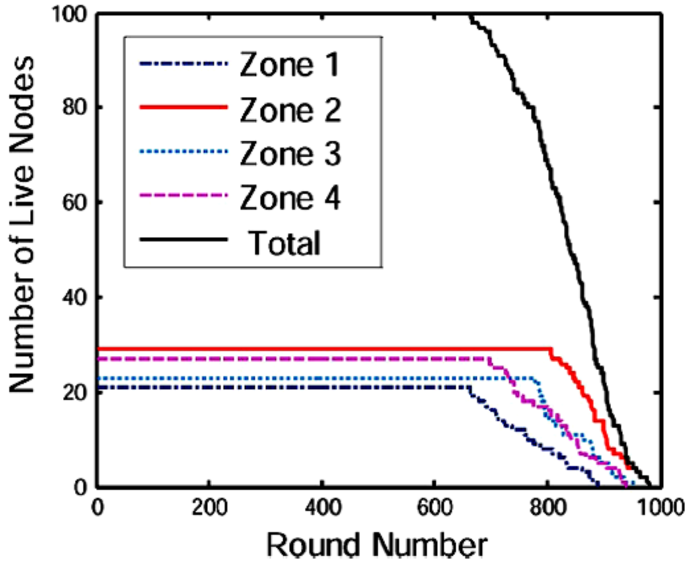


Fig. 6.Performance (number of live nodes versus round) after introducing theDFS into the rectangular sensor area.

IV. CONCLUSION

We investigated a modified energy-efficient communicationprotocol, called O-LEACH, for wireless sensor networks thatconsist of DFS links and randomly scattered wireless sensornodes. Survival round numbers of WSN nodes are simulated forvarious cases using different parameters. The lifetime of the situationthat two WSNs are isolated is more than 20% better thanthat of the case where nodes inside two WSN fields are reachableto any live nodes within the whole sensor field. This can bea deployment guideline for such hybrid sensor networks.

REFERENCES

[1] I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Asurvey on sensor networks," *IEEE Commun. Mag.*, vol. 40, no. 8, pp.102–114, Aug. 2002.

[2] J. M. Kahn, R. H. Katz, and K. S. J. Pister, "Next century challenges:Mobile networking for smart dust," in *Proc. ACMMobiCom'99*,Washington,DC, 1999, pp. 271–278.

[3] V. Rodoplu and T. H. Meng, "Minimum energy mobile wireless networks,"IEEE J. Sel. Areas Commun., vol. 17, no. 8, pp. 1333–1344,Aug. 1999.

[4] K. Sohrabi et al., "Protocols for self-organization of a wireless sensornetwork," IEEE Pers. Commun., pp. 16–27, Oct. 2000.
[5] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, "Energyefficient
communication protocol for wireless microsensor networks,"in IEEE Proc. Hawaii Int. Conf. Sys. Sci., Jan. 2000, pp. 1–10.
[6] X. Fan and Y. Song, "Improvement on LEACH protocol of wirelesssensor network," IEEE SENSORCOMM, pp. 260–264, 2007.
[7] H. Jeong, C.-S.Nam, Y.-S.Jeong, and D.-R. Shin, "A mobile agentbased LEACH in wireless sensor network," in Proc. Conf. AdvancedComm. Technol. (ICACT), Feb. 2008, pp. 75–78.
[8] X. Bao, D. J. Webb, and D. A. Jackson, "32-km distributed temperaturesensor using Brillouin loss in optical fiber," Opt. Lett., vol. 18, pp.1561–1563, 1993.
[9] D. Garus, T. Gogolla, K. Krebber, and F. Schliep, "Brillouinopticalfiberfrequency-domain analysis for distributed temperature and strain measurements," J. Lightw. Technol., vol. 15, no. 4, pp. 654–662, 1997.
[10] B. Huttner, J. Reecht, N. Gisin, R. Passy, and J. P. von derWeid, "Localbirefringence measurements in single-mode fibers with coherent opticalfrequency-domain reflectometry," IEEE Photon. Technol. Lett.,vol. 10, no. 10, pp. 1458–1460, Oct. 1998.
[11] S. M. Maughan, H. H. Kee, and T. P. Newson, "A calibrated 27-kmdistributed fiber temperature sensor based on microwave heterodynedetection of spontaneous Brillouin scattered power," IEEE Photon.Technol. Lett., vol. 13, no. 5, pp. 511–513, May 2001.
[12] J. C. Juarez, E. W. Maier, K. N. Choi, and H. F. Taylor, "Distributedfiber-optic intrusion sensor system," J. Lightw. Technol., vol. 23, no. 6,pp. 2081–2087, 2005.
[13] D. Iida and F. Ito, "Detection sensitivity of Brillouin scattering nearFresnel reflection in BOTDR measurement," J. Lightw. Technol., vol.26, no. 4, pp. 417–424, 2008.
[14] D. Kedar and S. Arnon, "Laser 'firefly' clustering; A new concept inatmospheric probing," IEEE Photon. Tech. Lett., vol. 15, no. 11, pp.1672–1624, Nov. 2003.
[15] S. Teramoto and T. Ohtsuki, "Optical wireless sensor network systemusing corner cube retroreflectors (CCRs)," IEEE Globecom'04, pp.1035–1039, 2004.
[16] D. Kedar and S. Arnon, "Second generation laser firefly clusters: Animproved scheme for distributed sensing in the atmosphere," Appl.Opt., vol. 44, no. 6, pp. 984–992, 2005.