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ICCSN 2016 Table of Contents

Preface	xiv
Conference Committees.....	xv

Session 1: Information Theory and Information Security

Parallel Bit Manipulation Processor for Communication Coding and Decoding	3
<i>Yuanhong Huo and Dake Liu</i>	
Differential Power Analysis Attack and Efficient Countermeasures on PRESENT	8
<i>Xiaoyi Duan, Qi Cui, Sixiang Wang, Huawei Fang, and Gaojian She</i>	
A Steganography Scheme in a Low-Bit Rate Speech Codec Based on 3D-Sudoku Matrix	13
<i>Xueshun Peng, Yongfeng Huang, and Fufang Li</i>	
An Approach to Identifying Cryptographic Algorithm from Ciphertext	19
<i>Cheng Tan and Qingbing Ji</i>	
The Encode and Decode Theory of Polar Code and Its Performance Simulating	24
<i>Xiaoting Du and Xianfan Xu</i>	
Research on BSS in Artificial Noise Aided Secure Communication	28
<i>Li Xinxin, Cai Xiaoxia, and Dong Wei</i>	
Performance Analysis for Physical-Layer Network Coding with Hierarchical Modulation	33
<i>Meng Tang, Jianhua Chen, Yufeng Zhang, and Yan Zhang</i>	
A Nonbinary LDPC Product Network Coding Scheme with Signal Space Diversity.....	38
<i>Chengxin Jiang and Zhanji Wu</i>	
Blind Identification for Turbo Codes in AMC Systems.....	43
<i>Ruilin Pei, Zulin Wang, Qiang Xiao, and Li Quan</i>	

Power Control for Buffer Limited Physical Layer Network Coding.....	48
<i>Meng Qingmin, Pang Fengmei, and Zou Yulong</i>	
A New Decryption Algorithm of the Quasi-Cyclic Low-Density Parity-Check Codes Based McEliece Cryptosystem.....	53
<i>Shuo Zhang, Wenhui Cao, Angyang Li, Wenjie Dong, and Liwei Shao</i>	
Performance Evaluation of Polling Scheme with Different Priority Service	58
<i>Cai Qing, Liu Qianlin, and Ding Hongwei</i>	
A Priority Differentiated and Multi-Channel MAC Protocol for Airborne Networks.....	64
<i>Dinghai Xu, Hengyang Zhang, Bo Zheng, and Leilei Xiao</i>	
An Efficient And Cost-Effective Context-Parsing Architecture For Dynamically Reconfigurable Cryptographic Processor	71
<i>Kai Luo</i>	

Session 2: Signal Processing and Application

Multidimensional Signal Processing and Modeling with Neural Networks in Metal Machining: Cutting Forces, Vibrations, and Surface Roughness.....	77
<i>N. Fang, P. Srinivasa Pai, and N. Edwards</i>	
Novel Signal Processing of Brain Activity Based on Ant Colony Optimization and Wavelet Analysis with Near Infrared Spectroscopy.....	81
<i>Xu Huang, Raul Fernandez-Rojas, Kengliang Ou, and Allan C. Madoc</i>	
DOA Estimation of Coherent Signals on Uniform Circular Array in the Presence of Mutual Coupling	86
<i>Li Shuai, Chen Hui, and Cong Haixia</i>	
Improved Propagator Method for Joint Angle and Doppler Estimation Based on Structured Least Squares.....	91
<i>Likai Guo and Ying Wu</i>	
Detecting Sports Fatigue from Speech by Support Vector Machine	96
<i>Shuxi Chen, Heming Zhao, Xueqin Chen, and Cheng Fan</i>	
A New Signal Analysis Method for Functional Near-Infrared Spectroscopy.....	100
<i>Zhang Zhongpeng and Hong Wenxue</i>	
A Novel Method of FECG Extraction Combined Self-Correlation Analysis with ICA.....	107
<i>Chaolan Li, Bin Fang, Huijie Li, and Pu Wang</i>	
A Multi-Component LFM Signal Parameters Estimation Method Using STFT and Zoom-FRFT	112
<i>Yongfei Ding, Le Sun, Hengyang Zhang, and Bo Zheng</i>	

Implementation of ECG Signal Processing Algorithms for Removing Baseline Wander and Electromyography Interference	118
<i>Changhsi Wu, Yanrong Zhang, Chengyo Hong, and Herlih Chiueh</i>	
Improved Eigenvalue-Based Spectrum Sensing via Sensor Signal Overlapping	122
<i>Liping Du, Mihir Laghate, Chunhao Liu, Danijela Cabric, and Yueyun Chen</i>	
An Improvement on Duty-Cycle Division Multiplexing Technique	127
<i>Chai Jia and Chen Xinqiao</i>	
Signal-Noise Separation of Sensor Signal Based on Variational Mode Decomposition	132
<i>Bin He and Yanping Bai</i>	
Multi-Lingual Unsupervised Acoustic Modeling Using Multi-Task Deep Neural Network under Mismatch Conditions	139
<i>Yao Haitao, Xu Ji, and Liu Jian</i>	
An Enhanced TKM-TR Method for PAPR Reduction of OFDM Signals with Peak Regrowth and Peak Residual Reduced	145
<i>Pingyuan Yu and Shubo Jin</i>	

Session 3: Communication and Information System

Research on Compressed Sensing of KL Domain with Limited Feedback in MIMO-OFDM System	151
<i>Fu Hongliang and Li Chao</i>	
A Novel Fingerprinting Positioning Approach in Urban Cellular Networks.....	155
<i>Belaabed Abdelghani and Gao Qiang</i>	
Performance Analysis of OSTBC-MIMO Systems Employing M-QAM Transmission over Independent But Not Necessarily Identical Generalized-K Fading Channels.....	160
<i>Jie He and Kun Xiao</i>	
A Standard BER Analysis for Two-Way Relay Networks at High and Optimal SNR Domains	166
<i>Muhammad I. Khalil, Stevan M. Berber, and Kevin W. Sowerby</i>	
Performance Analysis of a Multi-User Relay Selection Scheme with Predicted SINR in the Presence of Co-Channel Interference	171
<i>Cailing Qin and Kun Xiao</i>	
Rapid Address Allocation Method in Underwater Acoustic Array System.....	177
<i>Yanchao Li, Fajie Duan, and Jiajia Jiang</i>	
Performance Analysis of TAS/SC in MIMO Relay Systems with Outdated CSI in the Presence of Co-Channel Interference	181
<i>Feiyu Hou and Kun Xiao</i>	

Semi-Blind Interference Alignment in Frequency Selective Channels.....	186
<i>Lili Zheng, Zaichen Zhang, Liang Wu, and Jian Dang</i>	
Low Complexity MIMO Detection Algorithm by Combining Modified OSIC and ML Detection	192
<i>Saifullah Adnan, Zhang Linbo, Muhammad Ayoob Dars, and Muhammad Irshad Zahoor</i>	
A New Acquisition Method Based on Differential Correlation	196
<i>Sujuan Shang, Yanjun Hu, Jufeng Luo, and Yingguan Wang</i>	
Regularized Interference Alignment for Heterogeneous Networks.....	201
<i>Jinbo Zhang, Su Qu, and Hang Zhang</i>	
Large-Scale MIMO Detection Design and FPGA Implementations Using SOR Method.....	206
<i>Peng Zhang, Leibo Liu, Guiqiang Peng, and Shaojun Wei</i>	
Implementation and Measurement of Single User MIMO Testbed for TD-LTE-A Downlink Channels...	211
<i>Saeid Aghaeinezhadfirouzja, Hui Liu, Bin Xia, and Meixia Tao</i>	
The Time-Domain Equalization Research of Underground High-Speed Cable Transmission Based on OFDM and Its Realization in DSP	216
<i>Huafeng Fang, Dejun Liu, Xing Cheng, Jin Xu, and Qi Pan</i>	
On the Outage Probability in Cognitive Amplify-and-Forward Relaying Systems over Mixed Fading Channels for End User Mobile	221
<i>Lama N. Ibrahim, Mamoun F. Al-Mistarihi, and Mahmoud A. Khodeir</i>	
Dual Hop Differential Amplify-and-Forward Relaying with Selection Combining Cooperative Diversity over Nakagami-m Fading Channels.....	225
<i>Mariam M. Harb and Mamoun F. Al-Mistarihi</i>	

Session 4: Navigation System and Satellite Communication

Research on Non-Linear Fault-Tolerant Filtering for GPS/DR Integrated Navigation System	231
<i>Pei Dong and Qin Daguo</i>	
Anti-Interference Analysis of Multiplexing Methods for GBBF System	236
<i>Nan Lu, Xue Sun, Hao Huang, and Liwei Shao</i>	
Design and Implementation of Reliable Data Transmission System for Emergency Communications Based on 3G and BeiDou Navigation Satellite.....	241
<i>Ting Yi, Ming Che, and He Li</i>	

Session 5: Antenna Technology and Microwave Engineering

The Principle and Implementation of Monopulse Antenna Angle Error Signal Simulator.....	249
<i>Zheng Zhe, Zhai Jiahuan and Jia Dongrui, Zhou Leichen, and Zhou Yang</i>	

Transmit Beamforming Optimization for Energy Efficiency Maximization in Downlink Distributed Antenna Systems	254
<i>Jilei Yan, Wei Wu, Yue Wang, Guorui Yang, and Yantao Guo</i>	
The Radial-Based Noise Power Estimation Algorithm in the C-Band Dual-Polarization Doppler Weather Radar	260
<i>Tengwei Li and Tao Wang</i>	
Effects of Random Errors on the Radiation Pattern of Cylindrical Array Antenna	264
<i>Tan Jing, Cao Aihua, and Yao Nan</i>	
Design and Testing of Coupling Feed Linear Polarization Microstrip Antennas	269
<i>Yuehong Ma and Xiaolin Zhang</i>	
Space Millimeter-Wavelength Very Long Baseline Interferometry Simulation Software	274
<i>Tao An, Baoqiang Lao, Junyi Wang, Yang Lu, Yanheng Wei, and Xiaocong Wu</i>	
Outage Probability Performance Analysis of Multi-Antenna AF Relaying.....	280
<i>Ping Lai, Hang Bai, Jianjian Li, and Zheqing Shen</i>	

Session 6: Electronic and Communication Engineering

Research and Implementation of the Digital Intermediate Frequency in LTE Superheterodyne Transmitter.....	287
<i>Zhang Yuan, Yuan Xingmeng, Qin Jian, Xia Lei, Chen Chao, and Bao Minghui</i>	
Digital Down-Conversion Design and Implementation Based on FPGA	293
<i>Yingying Du, Xinjing Ye, Yafei Li, and Zhengyu Cai</i>	
RSS Based Method for Sensor Localization with Unknown Transmit Power and Uncertainty in Path Loss Exponent.....	298
<i>Daixin Li and Jiyang Huang</i>	
Advanced Double-Talk Detection Algorithm Based on Joint Signal Energy and Cross-Correlation Estimation	303
<i>A. A. M. Muzahid, K. M. R. Ingrid, S. I. M. M. Raton Mondol, and Y. Zhou</i>	
A New All-Digital Phase-Locked Loop Based on Single CPLD.....	307
<i>Weicong Shen and Fan Zhang</i>	
An Improved HCCA Mechanism for Safety Critical Real Time System	311
<i>Qiang Zhou and Pengwei Ma</i>	
Multi-Tone Interference Suppression in DSSS System Based on the Optimal Frequency Shift of Undecimated Wavelet Packets.....	316
<i>Lan Wang, Yuhong Yang, Pengxu Li, and Liangshan Li</i>	

Design of the Multi-Channel Data Acquisition System Based on YL-5000.....	320
<i>Xiao Mingyan and Su Shaojing</i>	
The Invulnerability of Robust Communication Network	325
<i>Wen Changjun and Zhang Xiaomeng</i>	
Design of Super Regenerative On-Off Keying Receiver for 5.8GHz ISM Band Short Range Applications	329
<i>Changhsi Wu, Jianchang Zhou, and Bochen Chen</i>	
Target Data Association in Communication Constrained Environment Using CART: Compressed Adaptive Reference Topology.....	333
<i>Yue Wang and Wang Yue</i>	
The Analysis of the Outdoor Powerline Channel in Zhengzhou	339
<i>Zhi Quan and Ting Tian</i>	
Analysis and Design of Hybrid Network for Distribution Automation System in China	343
<i>Qingrui Guo, Xu Wang, Yaping Li, Zhijun Zhang, and Peng Xie</i>	
The Analysis of the Effects of ASLC on MTD and Solutions.....	348
<i>Xiaowen Tang, Lingyan Dai, Rongfeng Li, and Fengbo Chen</i>	
A DC-20GHz Attenuator Design with RF MEMS Technologies and Distributed Attenuation Networks	352
<i>Qi Zhong, Xin Guo, and Zewen Liu</i>	
A Study of Fault Diagnosis of Nuclear Power Plant Clock System Based on Evidence Theory	356
<i>Shouyang Zhai and Bo Bai</i>	

Session 7: Network Resource Management

Uplink Resource Sharing of Multiple D2D Links Underlying Cellular Networks	365
<i>Qing Zhu, Yongbiao Yang, Shiming Xu, Yi Hu, Qi Tangm, and Fang Liu</i>	
Energy-Efficient Resource Allocation with 3D Beamforming in 3D MIMO-OFDMA Systems.....	370
<i>Zhe Li, Yueyun Chen, and Zhiyuan Mai</i>	
Cross-Layer Power Allocation Scheme for Wireless Full Duplex Relaying System	375
<i>Mengmeng He, Yanjun Hu, Hui Zhi, and Quan Yuan</i>	
Cross-Layer Power Allocation Scheme for Two-Way Amplify-and-Forward Relaying System.....	381
<i>Quan Yuan, Yanjun Hu, Hui Zhi, and Mengmeng He</i>	
Centralized Power Control Strategy for Small Packet Service in UMTS	387
<i>Yue Qiu, Yuping Zhao, and Dou Li</i>	

Spectrum and Energy Efficiency Analysis of Ultra Dense Network with Sleep	392
<i>Ce Zheng, Jiansun Fan, and Xinmin Luo</i>	
Energy Efficiency and Spectrum Efficiency Balance of Wireless Relay Networks	397
<i>Muhammad I. Khalil, Stevan M. Berber, and Kevin W. Sowerby</i>	
Low Complexity Pilot Allocation in Massive MIMO Systems.....	402
<i>Li Ku, Jiansun Fan, and Jianguo Deng</i>	
Joint Resource Allocation and Traffic Management for Cloud Video Distribution over Software-Defined Networks.....	407
<i>Zhenghuan Zhang, Xiaofeng Jiang, and Hongsheng Xi</i>	
System Utility Optimization of Cell Range Expansion in Heterogeneous Cellular Networks	412
<i>Haiqi Jiang</i>	
Spectrum Allocation of Cognitive Radio Network Based on Optimized Genetic Algorithm in Underlay Network.....	418
<i>Rixing Huang, Jie Chang, Yi Ren, Feng He, and Chun Guan</i>	
Hybrid-GA Based Static Schedule Generation for Time-Triggered Ethernet.....	423
<i>Li Bingqian and Wang Yong</i>	
Power Control Mechanism in Software Defined Wireless Networking	428
<i>Zeng Wang and Jinhe Zhou</i>	

Session 8: Wireless Sensor Networks

Error Beacon Filtering Algorithm Based on K-Means Clustering for Underwater Wireless Sensor Networks.....	435
<i>Linfeng Liu, Jingli Du, and Dongyue Guo</i>	
Analysis of Spectrum Utilization for ISM Band Cognitive Radio Sensor Networks	439
<i>Shensheng Tang, Chenghua Tang, Rong Yu, Xiaojiang Chen, and Yi Xie</i>	
Assessing Multi-Hop Performance of Reactive Routing Protocols in Wireless Sensor Networks	444
<i>Junhu Zhang and Zhenhua Sun</i>	
COCA: Congestion-Oriented Clustering Algorithm for Wireless Sensor Networks	450
<i>Khanh Le, Tho Quan, Thang Bui, and Laure Petrucci</i>	
A Self-Calibrated Centroid Localization Algorithm for Indoor Zigbee WSNs	455
<i>Tanveer Ahmad, Xue Jun Li, and Boon-Chong Seet</i>	
Energy Efficiency in Multi-Sink Linear Sensor Network with Adjustable Transmission Range	462
<i>Su Bing and Zhang Yujing</i>	

Session 9: Mobile Communication and Wireless Technology

A Novel Tree-Based Routing Protocol in ZigBee Wireless Networks	469
<i>Yang Liu and Keyuan Qian</i>	
WiFi Based Indoor Localization with Multiple Kernel Learning	474
<i>Heng Fan and Zhongmin Chen</i>	
A Simple Scheme to Generate Two Millimeter-Wave Signals for Radio-over-Fiber Systems.....	478
<i>Tao Yang, Mingyi Gao, and Jiaqin Qian</i>	
A Fast and Fair Rendezvous Guarantee Channel Hopping Protocol for Cognitive Radio Networks	483
<i>Chihmin Chao and Hsiangyuan Fu</i>	
Research on a Novel Strategy for Automatic Activity Recognition Using Wearable Device	488
<i>Zhiyuan Wei and Ting Bao</i>	
On Dynamic Migration of Virtual Router	493
<i>Tongbiao Li, Xiaozhe Zhang, Xianming Gao, and Shicong Ma</i>	
DMCSN: A Delay-Tolerant Architecture for Content Sharing in Mobile Network	500
<i>Chao Li and Huimei Lu</i>	
An Improved Scheme for Large Scale Complex Field Network Coding Based on User Clustering and Relay Selection Strategy in Wireless Cooperative Communication	508
<i>Yuwen Huang, Zhanji Wu, Chengxin Jiang, and Kun Lu</i>	
A Low Complexity Measurement Method for Beam-Forming Network Based on DSCDMA.....	514
<i>Shiguang Hao, Nan Lu, and Yunpeng Gao</i>	
A Wi-Fi-Based Indoor Positioning Algorithm with Mitigating the Influence of NLOS	520
<i>Wenfeng Li, Yueyun Chen, and Muhammad Asif</i>	
Design and Implementation of Multicast Routing System over SDN and sFlow	524
<i>Lei Huang, Xiaoli Zhi, Qiang Gao, Samina Kausar, and Shengan Zheng</i>	
Fast Positioning Scheme for UWB in the Multi-Path Environment	530
<i>Wang Xiuzhen, Hou Yanyan, and Liu Sanrong</i>	
A New Design of Pulse Waveform for Waveform Division Multiple Access UWB Wireless Communication System.....	535
<i>Zhendong Yin, Shaoxue Wu, Zhenguo Shi, and Zhilu Wu</i>	
A Novel Rear-End Collision Warning Algorithm in VANET	539
<i>Hexin Lv, Ping Xu, Huafeng Chen, Binbin Zhou, Tiaojuan Ren, and Yourong Chen</i>	
Fault-Tolerant Routing Method of NoC System Based on Clustering.....	543
<i>Jia Minzheng, Zhu Yunzhong, and Fu Fangfa</i>	

Session 10: Information Network and Multimedia Technology

A Blind Detection Method for Tracing the Real Source of DDoS Attack Packets by Cluster Matching	551
<i>Yonghong Chen, Xin Chen, Hui Tian, Tian Wang, and Yiqiao Cai</i>	
An Intrusion Detection Algorithm Based on Chaos Theory for Selecting the Detection Window Size	556
<i>Shan Wang, Yonghong Chen, and Hui Tian</i>	
A Soft-Output Error Control Method for Wireless Video Transmission	561
<i>Bo Zheng and Shaoshuai Gao</i>	
The Importance of K-Shell in Discovering Key Nodes in Complex Networks.....	565
<i>Hong Zhang, Changzhen Hu, and Xiaojun Wang</i>	
Application of Complexity and Brittleness on Software Architecture	570
<i>Hong Zhang, Changzhen Hu, and Xiaojun Wang</i>	
Dynamic Analysis of Coupled Binary Sawtooth and Sawtooth and Cow Patch Cellular Neural Networks	574
<i>Mian Wang, Lequan Min, and Min Li</i>	
Comparison Deep Learning Method to Traditional Methods Using for Network Intrusion Detection	581
<i>Bo Dong and Xue Wang</i>	
Network-Based Usage Monitoring and Rights Management of Digital Media.....	586
<i>Yi Xie and Yulin Wang</i>	
An Evaluation Method of Object-Oriented Petri Net on Combat Effectiveness of Air Defense and Antimissile.....	590
<i>Xiang Gao, Jun Tang, Yunxiang Ling, Cong Lu, Linjun Fan, and Yong Li</i>	
Hyper-DC: A Rearrangeable Non-Blocking Data Center Networks Topology.....	597
<i>Wang Renqun and Peng Li</i>	
Information Influence Measurement Based on User Quality and Information Attribute in Microblogging	603
<i>Miao Yu, Wu Yang, Wei Wang, and Guo Wei Shen</i>	

Session 11: Image Processing and Application

Evaluating the Complexity Degree of Electromagnetic Environment Utilizing Morphological Pattern Spectrum.....	611
<i>Dong Jun, Li Bing, Chen Shuangshuang, and Han Hui</i>	

A Multiple Target Measurement Retrieval Algorithm Based on K-Neighborhood Membership Degree P-PHD Filtering	615
<i>Wang Xue, Li Hong Yan, Tong Qian, and Pu Lei</i>	
A Pre-Training Strategy for Convolutional Neural Network Applied to Chinese Digital Gesture Recognition	620
<i>Yawei Li, Yuliang Yang, Yueyun Chen, and Mengyu Zhu</i>	
A Framework of Automatic Brain Tumor Segmentation Method Based on Information Fusion of Structural and Functional MRI Signals	625
<i>Xiaojie Zhang, Weibei Dou, Mingyu Zhang, and Hongyan Chen</i>	
Efficient Moving Object Segmentation Algorithm Based on the Improvement of Generalized Geodesic Active Contour Model	630
<i>Ying Chen and Qi Yu</i>	
Proposed Retinal Abnormality Detection and Classification Approach—Computer aided detection for diabetic retinopathy by machine learning approaches	636
<i>Valliappan Raman, Patrick Then, and Putra Sumari</i>	
Saliency Detection Based on Spatio-Frequency Information	642
<i>Shangwang Liu, Jianlan Hu, and Yanmeng Cui</i>	
Image Specific Target Detection and Localization Based on Locally Adaptive Regression Kernels Algorithm	647
<i>Kangjian He, Dongming Zhou, Rencan Nie, Xin Jin, and Quan Wang</i>	
Remote Sensing Image Edge-Detection Based on Improved Canny Operator	652
<i>Shi Guiming and Suo Jidong</i>	
Typical Nonlinear Dynamical Chaotic Images and Their Improvements	657
<i>Hongli Xu, Yuncheng Wang, and Zhuang Wu</i>	
Research of 3D Face Recognition Algorithm Based on Deep Learning Stacked Denoising Autoencoder Theory	663
<i>Jian Zhang, Zhenjie Hou, Zhuoran Wu, Yongkang Chen, and Weikang Li</i>	
An Image Display and Analysis System for Fluorescence Microscopic Sample	668
<i>Huan Jiang, Yu Wang, Changchun Zhang, and Xiaobin Zhu</i>	
Recognition Based Segmentation of Connected Characters in Text Based CAPTCHAs	673
<i>Rafaqat Hussain, Hui Gao, Riaz Ahmed Shaikh, and Shazia Parveen Soomro</i>	
High Resolution Remote Sensing Image Fusion Method Based on Curvelet and HCS	677
<i>Song Yang, Shengyang Li, Chenxin Chen, and He Zheng</i>	
Development of a Helium Gas Balloon Flying System for Aerial Photographing and Observation	681
<i>Elie N. Mambou, Gabriel M. Yamga, J. Meyer, and H. C. Ferreira</i>	

Session 12: Computer Science and Applications

Learning Three-Way Affinity Embeddings for Knowledge Base Completion	689
<i>Yu Zhao</i>	
Deploying an Ad-Hoc Computing Cluster Overlaid on Top of Public Desktops	693
<i>Henry Novianus Palit</i>	
EnergyMap: Energy-Efficient Embedding of MapReduce-Based Virtual Networks and Controlling Incast Queuing Delay	698
<i>Ebrahim Ghazisaeedi and Changcheng Huang</i>	
Emulation Platform for Dedicated to Adaptive MPSoC-Based NoC Architecture for the Art Authentication Application	703
<i>Junyan Tan and Di Hua</i>	
Comparative Analysis of List Scheduling Algorithms on Homogeneous Multi-Processors	708
<i>Jian Wang, Xinke Lv, and Xiao Chen</i>	
Research on the Assistant System of Stage Management Based on Android	714
<i>Yujian Jiang, Shaobo Wang, Wei Jiang, and Xiru Guan</i>	
High-Performance Implementation of SM2 Based on FPGA.....	718
<i>Dan Zhang and Guoqiang Bai</i>	
Reconfigurable Simulation Platform for Application Design and Development	723
<i>Yuan Haibin and Wu Qicai</i>	

Author Index

Author Profile



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Subjects/Areas:

 ID

[Distributed Computing](#) [Cloud Computing](#) [Big Data Analysis](#)



13.95

Overall Score

1.63

3 Years Score

1231

Overall Score V2

161.5

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0

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Page 1 of 3 | Total Records : 22

Quartile	Publications	Citation
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–	Linux PAM to LDAP authentication migration Proceedings – 2017 International Conference on Soft Computing, Intelligent System and Information Te vol: 2018–January issue : I 2017–07–02 Conference Proceedin	2
Q3	Proxy-based pervasive multimedia content delivery. Proceedings – International Computer Software and Applications Conference vol: 1 issue : I 2006–12–01 Conference Proceedin	1
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Page 1 of 3 | Total Records : 22

Page 2 of 3 | Total Records : 22

Quartile	Publications	Citation
–	An efficient co-processing framework for large-scale scientific applications Proceedings of the International Conference on Cloud Computing Technology and Science, CloudCom I vol: 2015–February I issue : February I 2015–02–09 I Conference Proceedin	1
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–	Using TCOZ for modeling web caching Proceedings of the Asia-Pacific Software Engineering Conference and International Computer Science C I vol: I issue : I 2001–12–01 I Conference Proceedin	0
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Page 2 of 3 | Total Records : 22

Page 3 of 3 | Total Records : 22

Quartile	Publications	Citation
–	<u>Deploying an Ad-Hoc computing cluster overlaid on top of public desktops</u> Proceedings of 2016 8th IEEE International Conference on Communication Software and Networks, ICCSN I vol: I issue : I 2016-10-07 I Conference Proceedin	0
–	<u>Preface</u> Proceedings – 2017 International Conference on Soft Computing, Intelligent System and Information Te I vol: 2018-January I issue : I 2018-01-16 I Conference Proceedin	0
Q2	<u>Comparative Analysis of NFS and iSCSI Protocol Performance on OpenStack Cinder Technology.</u> Procedia Computer Science I vol: 171 I issue : I 2020-01-01 I Conference Proceedin	0

Page 3 of 3 | Total Records : 22



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Deploying an Ad-Hoc Computing Cluster Overlaid on Top of Public Desktops

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Abstract—A computer laboratory is often a homogeneous environment, in which the computers have the same hardware and software settings. Conducting system tests in this laboratory environment is quite challenging, as the laboratory is supposed to be shared with regular classes. This manuscript details the use of desktop virtualization to deploy dynamically a virtual cluster for testing and ad-hoc purposes. The virtual cluster can support an environment completely different from the physical environment and provide application isolation essential for separating the testing environment from the regular class activities. Windows 7 OS was running in the host desktops, and VMware Workstation was employed as the desktop virtualization manager. The deployed virtual cluster comprised virtual desktops installed with Ubuntu Desktop Linux OS. Lightweight applications using VMware VIX library and shell scripts were developed and employed to manage job submission to the virtual cluster. Evaluations on the virtual cluster's deployment show that we can leverage on desktop virtualization to quickly and dynamically deploy a testing environment while exploiting the underutilized compute resources.

Keywords—desktop virtualization; overlay virtual cluster; exploiting idle resources

I. INTRODUCTION

It is well known that the resource utilization in a data center is considerably low. According to an IBM Research Report [1], the CPU utilization of various data centers across continents ranges from 7% to 25%. Previous study [2] also found that the average daytime utilization of Windows servers is around 5%, whereas it is 15-20% among UNIX servers. Inquired by the New York Times [3], the consulting firm McKinsey & Company estimated that only 6% to 12% of the electricity powering the data centers is really used to perform computations. The majority of the electricity is used to keep servers idling and ready in case of a surge in activity.

Resource utilization in a university's computer laboratory can only be worse than that in a data center since the computers in the former are often turned on from morning till evening even though there is no class or practicum session going on. A computer laboratory is often a homogeneous environment, in which the computers have the same hardware and software settings. It would be an excellent environment for conducting system tests, if we could configure the computers freely. However, since it is supposed to be shared with regular classes, computer

configurations in the laboratory often cannot be disturbed, lest changes to those configurations would bring some disruption to the regular classes. This condition further causes underutilization of computers in the laboratory. Domingues *et al.* [4] concluded that the average CPU idleness of desktop computers in computer laboratories was near 98%. Among workstation clusters, a study by Acharya *et al.* [5] found that their idle time (i.e., when a cluster of a particular number of workstations is free) was up to 80%. Han and Gnawali [6] asserted that 60% of energy consumed in a computer laboratory was wasted, because the computers were on and no one was logged in. Further, they studied the laboratory users' behavior and concluded that only 5% of users used the computers extensively (consuming more than 3,000 KJ of energy), whereas the majority (75%) consumed less than or equal to 1,000 KJ of energy. Hence comes the idea to utilize the laboratory's computers for other purposes. These idle resources have been targeted for harvest and used for analyzing data, rendering movies, running some simulation models, and so forth.

Computer laboratories in our department suffer the same inefficiency in resource utilization. The potential of this multitude of idle computers is huge as each machine has a four-core processor and at least 8 GB of memory. Separately, there is a growing demand for computer resources to analyze a large amount of data (often termed as big data). Although the computation demand is high, the resource requirements of big data analytics often can be fulfilled by off-the-shelf computers. Obviously we should be able to match these unfulfilled demands with those excess supplies.

Consequently, we devise a simple, lightweight, and non-invasive mechanism to deploy a virtual cluster on the idly running computers in our laboratory. The overlaid, virtual cluster does not disturb the existing computer configurations and in fact, if necessary, both schemes (i.e., the virtual cluster and the native physical computers) can run concurrently in the laboratory. The virtual cluster can be exploited to address the big data issues, perform a distributed computing batch job, or even conduct an extensive system test. Although there are available solutions for automated deployment of virtual machines, we opt for creating our own solution due to the following reasons:

- The existing solutions (e.g., cloud management tools) entail major configuration changes to the computers, such as replacing the existing OS with a bare-metal hypervisor.

- The existing solutions are commonly heavyweight requiring many services or libraries to be in place to support them.
- Most of the existing solutions do not support Windows as the host OS, while the use of Windows OS is essential in our computer laboratories to hold regular classes.

Our proposed solution can overcome the issues that come with the existing solutions. It leaves the existing Windows OS and software configurations on each computer intact, needs no extra services or libraries, and supports deployment and termination of the virtual cluster on demand. We employ VMware and our developed VIX-based [7] applications running on Windows 7 to deploy the virtual cluster.

The rest of the paper is organized as follows. Section 2 presents some related work. Section 3 describes our proposed solution. Evaluation on the solution is discussed in Section 4. We conclude our findings and suggest some future work in Section 5.

II. RELATED WORK

Harvesting idle compute resources has been the subject of many studies. After the success of SETI@home project [8], which has employed millions of voluntary computers worldwide to process radio signals in the search for extraterrestrial intelligence, the U.C. Berkeley Spaces Sciences Laboratory has developed a platform for public-resource distributed computing called BOINC (Berkeley Open Infrastructure for Network Computing) [9]. One of its goals is to encourage the world's computer owners to participate in one or more scientific projects by contributing their unused resources (e.g., CPU, memory, disk space, and network bandwidth) and specifying how the resources are allocated among the projects.

The Condor project (renamed to HTCondor in 2012) [10] was started in 1984 at the University of Wisconsin. Similar to BOINC, every Condor's participant has the freedom to contribute as much or as little as s/he wants. Three parties are involved in the system: agents, resources, and matchmakers. The agent enforces the submitting user's policies on what resources are trusted and suitable for the user's jobs. The resource enforces the machine owner's policies on what users are to be trusted and served. The matchmaker enforces communal policies like limiting a particular user to consume too many machines at a time. Unlike BOINC, which is just one large pool of compute resources, there are multiple Condor pools – which may or may not collaborate with each other – around the globe.

Some institution may have spare processing capacity on its desktop PCs and it can pool these resources to execute the institution-level applications. Such practice is often termed as desktop grid [11]. In this case, the desktops' participation is usually obligatory and governed by the institution's policies.

BOINC, Condor, and desktop grid require some services – at least the CPU-load and job monitoring agents – to be installed on the participating computers. The services are imperative to the decision-making and execution flow of a distributed computing system. However, these background

running services would nip some resources from the participating computers, as they need to capture the current status and update the central server on a regular basis.

Other studies tried to exploit idle compute resources, either from a computer laboratory [5], [12], [13] or a data center [14], for parallel computation. In that case, there should be multiple computers available for a certain period of time to accomplish the parallel execution. Monitoring agents and adaptive scheduler are the key components in the scheme. The studies demonstrate that the scheme can work smoothly with minimal disturbance to the rightful jobs or users. However, sequential or embarrassingly parallel applications, as attested in Conillon [13], are still preferred as they impose the least impact.

Recently virtualization has been employed as the means to utilize idle compute resources. Compared to the physical environment, the virtual counterpart has added features like isolation, security, and fast deployment. HP Labs' researchers and their collaborators developed vCluster [15] and I-Cluster [16] that can switch workstation nodes between user-mode (Windows) and cluster-mode (Linux). A node in user-mode can automatically switch to cluster-mode when user idleness is detected, and likewise, it can switch back to user-mode when user presence is detected (or anticipated). The virtual cluster – comprising idle workstation nodes – can be used for various computation purposes, in isolation from the user's local data and applications. A different approach leveraged by NDDE [17] is to run virtual machines, in concurrence with the user's environment, to utilize the idle cycles. In that way, there is no need to switch between different environments. Both environments can run together independently, without interfering each other; the user may not even be aware of the presence of the virtual environment.

Meanwhile, the proliferation of cloud computing may drive server consolidation in many enterprises. Employing open-source cloud management software like Eucalyptus [18] and OpenStack [19], an enterprise can consolidate underutilized servers, and instead, deploy (virtual) servers on demand to improve the overall utilization of its compute resources. Subsequently, idle computer cycles can be used for accomplishing other computation tasks. While this approach is very effective in harvesting idle computer cycles, its adoption in our computer laboratory is impractical since the physical computers in the laboratory cannot be consolidated and should be left intact for the regular class activities.

Considering and evaluating all the above alternatives, we opted to employ desktop virtualization to utilize the idle computer cycles. The solution does not disturb much the existing computer configurations and can run in subtlety without interrupting normal laboratory usage.

III. OVERLAY VIRTUAL CLUSTER

In this section, we explain how the virtual environment is set up within a physical computer and how the virtual machines are assigned to form the virtual cluster. The virtual cluster is overlaid on top of the physical computers and network connectivity. Some illustrations are provided to explain our concept.

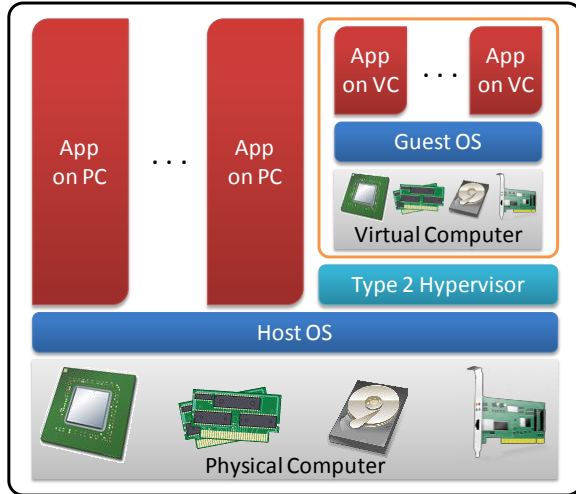


Figure 1. Physical and virtual environments within a computer

A. Deploying the Virtual Environment

For regular class and practicum activities, Windows 7 is the default OS running in our laboratory's computers. To facilitate a virtual environment, a desktop virtualization manager needs to be installed on each physical computer (PC). It employs a Type 2 hypervisor, which runs on top of the host OS. In our case, VMware Workstation is running on top of Windows 7 OS. A virtual computer (VC), a.k.a. virtual machine, can in turn be deployed with the hypervisor's help.

As seen in Figure 1, the physical computer can still be used by any user; existing applications (on PC) can run as per normal. The hypervisor can be considered as another application running on the physical computer. Once a virtual computer is deployed on top of the hypervisor, we can also run many applications (on VC) in the virtual domain. Hence, the physical and virtual environments can coexist together within a computer.

B. Building the Virtual Cluster

In a common computing cluster, one computer should act as the master whereas the rest are workers. Jobs (i.e., any computation tasks) are sent to the master node, which in turn distributes the jobs among the worker nodes and execute them remotely. By executing a job in parallel or concurrently, the job can be completed quickly. The master node also monitors the job's execution progress. Once the job is completed, results that are stored in the worker nodes are then collected by (or, sent to) the master node to be returned to the job's owner.

Similarly, in our virtual platform, as shown in Figure 2, one master node and multiple worker nodes can be dynamically deployed for executing computation jobs. The master node needs to be deployed first, and then followed by deploying the worker nodes. The master node has a list of active worker nodes. Each worker needs to register and deregister itself to that master's list when it is turned on and turned off, respectively. Therefore, the master node knows where to distribute and monitor the jobs.

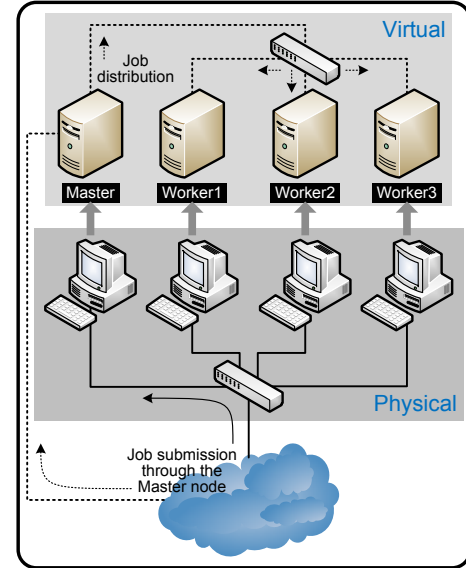


Figure 2. Physical and virtual clusters

The master and worker nodes in the virtual platform were running Linux OS. The operations to register and deregister a worker node were implemented in shell script, and so were those to distribute and execute jobs remotely. To automate the virtual cluster's (i.e., master and worker nodes) deployment, we developed lightweight applications using VIX (Virtual Infrastructure eXtension) API [7], which is a VMware library for writing scripts and programs to manipulate virtual machines. Multiple virtual machines may be hosted within a physical desktop. Thus, we have two deployment alternatives: one virtual machine per host and multiple virtual machines per host. We will evaluate both alternatives in the next section.

Figure 2 clearly illustrates the deployment of a virtual computing cluster on top of a physical cluster of desktops. Both platforms, physical and virtual, can run concurrently as far as the resources permit. In that way, the overall computers' utilization can be improved, and the laboratory's main responsibility – i.e., to support class and practicum sessions – is not disturbed. Moreover, the virtual computing cluster can be deployed on demand, at any convenient time, and perhaps remotely.

IV. SYSTEM EVALUATION

As a proof of concept, we had developed the system's prototype to demonstrate the benefits of the proposed scheme. Four desktops in our laboratory were used for the experiment. The specifications of each desktop are as follows:

- Processor: Intel Core i5-3340, quad-core, 3.1GHz
- RAM: 16GB
- Host OS: Windows 7 Professional SP1
- Virtualization manager: VMware Workstation 9.0.0 build-812388
- Guest OS: Linux Ubuntu Desktop 12.04

The above-mentioned VIX-based applications were developed and can be used by any user to direct and interface

with the VMware Workstation Managers (residing in the physical desktops). The virtual cluster can be deployed dynamically, meaning that the user can specify which physical desktops to employ and how many worker nodes to be deployed on each machine. At the moment, the virtual cluster can be used to execute embarrassingly parallel jobs, which do not require much communication between processing components. The jobs can either be direct or indirect tasks. A direct task means the program (i.e., can also be a command or a script) is available and can be executed directly in the worker nodes; e.g., executing Unix commands `ls`, `ps`, `date`, `curl`, etc. If the program is currently available in the user's computer, and not available in the worker nodes, then it is considered an indirect task. When executing an indirect task, the would-be-executed program in the user's computer is firstly transferred to the master node, and then it is distributed to the worker nodes, and finally it is executed concurrently on each worker node. In either kind of task, all screen outputs are collected and returned to the user's computer requesting the job execution.

We do not evaluate the different execution timings between physical and virtual clusters, as it is common knowledge that execution in the virtual environment incurs some penalty (variably between 1% and 15%) compared to that in the native environment. Instead, we evaluate the time needed to deploy different configurations of virtual clusters. The purpose of this evaluation is to determine which deployment is the fastest to deploy and to execute.

Referring to Table 1, the different configurations of the virtual clusters are 1 master + 2 workers on 1 host (2-on-1), 1 master + 2 workers on 2 hosts (2-on-2), 1 master + 3 workers on 1 host (3-on-1), and 1 master + 3 workers on 3 hosts (3-on-3). The master node is always deployed first, exclusively in a physical desktop. Once it is ready, the worker nodes are started one after another. Two schemes are evaluated: sequential and concurrent strategies. In the sequential strategy, the next worker node is started only after the currently started worker node is in a ready state (i.e., the VMware Tools daemon is successfully started). By contrast, in the concurrent strategy, the next worker node is immediately started without waiting for the currently started worker node's readiness.

TABLE I. AVERAGE DELIVERY TIMES (IN SECONDS) OF DIFFERENT CLUSTER CONFIGURATIONS

Cluster Configuration	Sequential-Start		Concurrent-Start		Stop
	Master	Workers	Master	Workers	
2-on-1 (2 workers on 1 host)	15.57	47.12	15.20	27.63	14.02
2-on-2 (2 workers on 2 hosts)	15.36	46.78	15.91	23.80	12.90
3-on-1 (3 workers on 1 host)	15.88	72.60	15.73	36.16	14.81
3-on-3 (3 workers on 3 hosts)	15.28	67.21	15.57	27.61	13.12

The delivery times – measuring the time taken until the execution is completed (i.e., when all nodes are ready or when they all are down) – of different cluster configurations are presented in Table 1. Deploying the master node takes between 15 and 16 seconds. Deploying the worker nodes, on the other hand, takes a longer time. In the 2-on-1 sequential strategy, it takes about 47.12 seconds (or, roughly 23.56 seconds per node). The 3-on-1 sequential strategy yields a similar result, about 24.20 seconds per node. Deploying the worker nodes in different hosts improves the results slightly (0.7% and 7% improvements in the 2-on-2 and 3-on-3 sequential strategies, respectively). The concurrent strategies produce much better results than the sequential counterparts. The performance gains are quite significant (i.e., 1.7 – 2.0 times and 2.0 – 2.4 times faster for 2 and 3 worker nodes, respectively).

Terminating (stopping) the virtual cluster takes about 13–15 seconds. Generally, the terminations in multiple hosts yield slightly better delivery times than those in a single host (about 8% and 11% improvements in the 2-on-2 and 3-on-3 cases, respectively).

Lastly, we evaluated the job execution – both, direct and indirect tasks – in different cluster deployments. We executed various jobs, from shell scripts to simple programs. Executing jobs in different cluster deployments produces pretty consistent delivery times, no matter whether the jobs are direct or indirect. Thus, the job execution is not affected by the different cluster deployments.

V. CONCLUSION AND FUTURE WORK

Most computer laboratories have very low resource utilization. Various schemes had been proposed to improve the resource utilization. However, majority of the schemes require some changes to the computer installation, and some may nip a portion of the resources for running essential background processes. In a computer laboratory where the hardware and software settings shall not be disturbed, lest they cause disturbance to regular classes or practicum sessions, such schemes cannot be employed.

Leveraging on desktop virtualization, our proposed scheme is lightweight, can be deployed on demand and at any time, and does not disturb much the computer installation in the laboratory. Evaluation on different cluster deployments shows that deploying the virtual nodes in multiple hosts, in contrast to deploying them in a single host, can slightly reduce the delivery times. However, deploying the virtual nodes concurrently, in contrast to deploying them sequentially, can yield performance gain by a factor of around 2 (for up to 3 worker nodes). The delivery times of executing direct or indirect jobs are not affected by the different cluster deployments.

Presently, the user has to give commands to the VMware Workstation Managers (i.e., executing the VIX-based applications) through the Windows (DOS) command prompt window. We intend to improve this in future work by developing a Web-based user interface. Additional VIX-based applications are also in our plan to provide features like data transfers and scheduled job execution.

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CERTIFICATE OF PARTICIPATION

Paper Title: Deploying an Ad-Hoc Computing Cluster Overlaid on Top of Public Desktops (S64)

This is to certify Henry Novianus Palit from Petra Christian University, Indonesia has attended and delivered an oral presentation on 2016 8th IEEE International Conference on Communication Software and Networks (ICCSN 2016) held in Beijing, China during June 4-6, 2016.

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