GLOBAL KIOSK OF HIGHER EDUCATION & SCHOLARSHIP: Emerging Mega Alliance of High Performance Research and Education Networks (REN)

Dr. Javed I. Khan

Networking and Media Communications Research Lab
Professor, Kent State University, Ohio
Fulbright Senior Specialist, ICT For Higher Education

Abstract

• In a silent revolution (started roughly around year 2000) 100 countries around the world have built advanced Research and Communication Networks (RENs). Now a global dream is being pursued further crossconnecting national RENs creating an unprecedented advanced global REN-aiming towards a global kiosk of innovation and scholarship. This three part talk presents the progress and state of the emerging Global REN, a glimpse of the new generation applications on the horizon, and their implications for nations- for sure which is poised to change the higher education landscape as we know it.
Universities in Transition

• Mission- "facilitation of learning".

• Learning Tools: Make available all the tools necessary for learning to the learner and the teacher (books, journals, laboratories)

• Meeting Place of Ideas: Provide a stimulating and safe environment for the quest for new ideas. It fosters dialogue based on intellectual merit and free from all other prejudice and fear (academic freedom).

• The above is the only known formal institutional means to harvest human knowledge
ICT and Universities

- ICT used to be an auxiliary service for universities in the 1990’s.
- In 2000’s it became an essential limb.
- In 2005 it is becoming the central artery in the running of modern universities.
- Almost all the countries in the world have adopted REN as the centerpiece of their information and communication technology (ICT) plan for higher education.
- Now about 92 countries around the world have REN-- 25+ more are building.
- The concept is marching further forward. Countries worldwide are now forming mega REN alliances of continental proportion with a vision of creating a world community of universities— a grand kiosk of higher education and scholarship.
US universities always needed a network one step ahead..
Internet2 Network Environment

Green states have Educational Group Participants
Internet2: Organization

• Internet2
  • The “brain” providing intellectual and technical leadership. A non-profit corporation of 207 member universities.

• Lambda Rail/Abilene
  • Internet2’s high performance backbone network with 10 Gbps (OC-192) capacity.

• A Set of Taskforces
  • Leading the creation of new applications and services and directions for Internet2.
    • Network and Middleware
    • Applications
ISP or REN?

- ISP’s business model is to satisfy vast pool of general customers, while university is a very special type of customer.

- Security, performance, and applications considerations are very different for Universities.

  - Universities need to experiment with new protocols.
  - Most ports are blocked. Security is old styled, and now blocking services.
  - Experimental protocols are seldom realized/deployed.
  - Many newer services and applications contradict conventional pricing model and thus acts as a disincentive.

- REN is a worldwide phenomena now (service at cost).
- More recently RENs a moving towards dark fiber to further obtain unrestricted capacity links to run much more capable protocols.
Global Trend

Not Just in USA now the idea of REN is spreading all over the world.
REN A World Phenomenon

<table>
<thead>
<tr>
<th>Region</th>
<th>Installed</th>
<th>In Progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFRICA</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td>ASIA</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td>AUSTRALIA</td>
<td>1</td>
<td>0</td>
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<tr>
<td>EUROPE</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>NORTH AMERICA</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>SOUTH &amp; CENTRAL AMERICA</td>
<td>11</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>92</strong></td>
<td><strong>24</strong></td>
</tr>
</tbody>
</table>

- **Current MoU Partners**
- **Developing Partnerships**
- **Related Efforts in Formation**

Khan, ICICT, Karachi, 2007
**Internet2 International Partners**

**Europe-Middle East**
- ARNES (Slovenia)
- BELNET (Belgium)
- CARNET (Croatia)
- CESnet (Czech Republic)
- DANTE (Europe)
- DFN-Verein (Germany)
- FCCN (Portugal)
- GARR (Italy)
- GIP-RENATER (France)
- GRNET (Greece)
- HEAnet (Ireland)
- HUNGARNET (Hungary)
- Israel-IUCC (Israel)
- NORDUnet (Nordic Countries)
- POL-34 (Poland)
- Qatar Foundation (Qatar)
- RedIRIS (Spain)
- RESTENA (Luxemburg)
- RIPN (Russia)
- SANET (Slovakia)
- Stichting SURF (Netherlands)
- SWITCH (Switzerland)
- JISC, UKERNA (United Kingdom)

**Asia-Pacific**
- AAIREP (Australia)
- APAN (Asia-Pacific)
- ANF (Korea)
- CERNET, CSTNET, NSFCNET (China)
- JAIRC (Japan)
- JUCC (Hong Kong)
- SingAREN (Singapore)
- NECTEC / UNINET (Thailand)
- TANet2 (Taiwan)
- NGI-NZ (New Zealand)
- TERENA (Europe)
- MyREN (Malaysia)

**Americas**
- CANARIE (Canada)
- CLARA (Latin America & Caribbean)
- CEDIA (Ecuador)
- CNTI (Venezuela)
- CR2Net (Costa Rica)
- CUDI (Mexico)
- REUNA (Chile)
- RETINA (Argentina)
- RNP [FAPESP] (Brazil)
- SENACYT (Panama)

**Asia-Pacific**
- MCIT [EUN/ENSTINET] (Egypt)
- TENET (South Africa)

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**Abilene International Network Peers**

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Last updated: 1 October 2005
• 10Mbps to Japan (APAN)
• Within China:
  • 16x2.5G DWDM system (two lambda’s are currently running)
  • OC48 POS links to 8 cities
  • OC3 POS SDH links to all provincial capitals (except Lhasa)
• unicast and multicast
Korea- KOREN/KREONET2

- Sharing 45mbps link across Pacific to STAR TAP
  - KREONET2 is led by KISTI and funded by Ministry of Sci & Tech
  - KOREN is funded by Ministry of Info and Comm and operated by Korea Telecom
SuperSINET Sites

- SINET national backbone network for higher education
- SuperSINET for research projects (~14 versus 300 SINET universities)
  - 10gbps backbone in Japan
  - 155mbps Abilene in Sunnyvale
• Currently 27mbps across Pacific
  • Peers with Abilene in Sunnyvale
  • 45mbps PVC to STAR TAP/AADS switch
Thailand- UNINNET

- Funded by Ministry of University Affairs in Thailand
  - Connects most universities in Thailand
  - Via 155mbps links
  - Currently has 10mbps PVC to Los Angeles
  - Peers with Abilene in L.A.
  - Other major net in Thailand is run by NECTEC (Ministry of Science & Tech funding)
Canada- CA*net/CA*net 4

- Wavelength-based
- regional networks
• +71 universities

• International connections:
  • EUA: via Tijuana – San Diego (transit via CALREN2 to Abilene) at 155Mbps
  • 100Mbps between Ciudad Juarez and El Paso (to Abilene)
  • vBNS via Houston
Ecuador - CEDIA www.internet2.edu.ec

- CEDIA: Consorcio Ecuatoriano para el Desarrollo de Internet Avanzado.
- September 2002: launch ceremony
- October 2003, National Backbone CEDIA operational
- 15 Universities, 2 research centers and 2 government agencies.
• Red Universitaria Nacional – REUNA
• 10 POP’s from Arica to Valdivia
• 155 Mbps ATM/SDH Network
• over 30 universities
• Internet - Internet2 services
• 45 Mpbs to AMPATH
• G-REUNA:
  • backbone project
  • Gigabit and application test-bed
  • 140 km dark fiber, Santiago to Valaparaiso
• Red Teleinformática Académica
• Red RETINA:
  • ~25 institutions
  • International connection: 45 Mbps to AMPATH
• Abundance of fiber in main cities but challenge is expanding reachability into rest of country, plus other issues
Brazil – Sao Paulo http://www.ansp.br

- Funded by FAPESP
- Sao Paulo’s university networks and research centers
- Connect at 45 Mbps to AMPATH
- RNP PoP in Sao Paulo peers with ANSP

Source: http://www.ansp.br
Ireland- HEANET www.heanet.ie

- Serves the Irish universities
- Using 2 of several OC3 (155mbps) links to peer in NYC
- Upgrading backbone to 155mbps
The NORDUnet Network

- Connects together networks of Denmark, Iceland, Finland, Norway and Sweden
- Reworking 622mbps to New York (plus 155 to StarLight)

Providing transit to RUNNET (Russia), EENET (Estonia), UARNET (Ukraine) and NASK (Warsaw, Poland)
“if you think education is expensive try ignorance”

-Derek Bok, President Emeritus, Harvard
TERENA: Core network capacity
External Connectivity

Graph 3.5.1 Division of External Connectivity over the Categories, January 2006

Graph 3.5.2 External Connectivity > 10 Gb, January 2006
Connection Policy

- All NRENs connect universities, research institutes and, with few exceptions, institutes of higher education.

- Many NRENs also connect secondary and primary institutions, though there are great differences in policy.

- Some NRENs connect government departments that have a relation to research and education, etc.
Graph 2.4.1 University Bandwidth, EU/EFTA Countries

Graph 2.4.2 University Bandwidth, Other Countries

Legend:
- x > 10 Gb
- 10 Gb < x ≤ 1 Gb
- ISDN < x ≤ 2 Mb
- 1 Gb < x ≤ 10 Gb
- 10 Mb < x ≤ 100 Mb
- 0 ≤ x ≤ ISDN
- x = 1 Gb
- 2 Mb < x ≤ 10 Mb
Global Trend

Global REN: And now national RENs are connecting to each other creating advanced research and higher education network of continental proportion…
# Federation of RENs

<table>
<thead>
<tr>
<th>Network</th>
<th>Name</th>
<th>Region</th>
<th>Members</th>
</tr>
</thead>
<tbody>
<tr>
<td>APAN</td>
<td>Asia-Pacific Advanced Network</td>
<td>All Asia</td>
<td>All Asia</td>
</tr>
<tr>
<td>TEIN2</td>
<td>Trans-Eurasia Information Network</td>
<td>Asia Pacific</td>
<td>Australia, China, Indonesia, Korea, Malaysia, The Phillipines, Thailand and Vietnum with Europe</td>
</tr>
<tr>
<td>EUMEDCONNECT</td>
<td>Europe and Mediterranean Education Network Connect</td>
<td>Mediterranean</td>
<td>Algeria, Cyprus, Egypt, Israel, Jordan, Lebanon, Malta, Morocco, The Palestinian Authority, Syria, Tunisia and Turkey</td>
</tr>
<tr>
<td>Nordunet</td>
<td>The Nordic Internet Highway to Research and Education Networks</td>
<td>Nordic Europe</td>
<td>Denmark, Finland, Iceland, Norway and Sweden</td>
</tr>
<tr>
<td>GEANT2</td>
<td>Network for Southeast Europe</td>
<td>All Europe</td>
<td>30 RENS from all Europe</td>
</tr>
<tr>
<td>ALICE</td>
<td>America Latina Interconectada Con Europa</td>
<td>Latin America</td>
<td>Argentina, Brasil, Chile, Costa Rica, Guetemala, Mexico, Panama, Paraguay, Peru, Uruguay, Venezuela, Bolivia, Columbia, Honduras, Nicaragua, Cuba, El Salvador, and Ecuador</td>
</tr>
<tr>
<td>ERNESA</td>
<td>The Educational Research Network in East and Southern Africa</td>
<td>East and Southern Africa</td>
<td>Botswana, Ethiopia, Kenya, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Uganda, Zambia and Zimbabwe</td>
</tr>
<tr>
<td>ERNWACA</td>
<td>The Education Research Network for West and Central Africa</td>
<td>West and Central Africai</td>
<td>Benin, Burkina Faso, Côte d'Ivoire, Ghana, Guinea, Mali, Nigeria, Senegal, Sierra Leone and Togo</td>
</tr>
</tbody>
</table>
GEANT (http://www.dante.net/geant/)

- 31 countries connecting
- Operated by DANTE
- 10 Gbps core backbone
  - Connectors at 10Gbps(2) and below
- Total of 4x2.5Gbps + 2x1Gbps across Atlantic (DANTE & EuroLink provided)
Europe – International connectivity

REF: Report on present status of international connectivity in Europe and to other continents, From SERENATE – Study into European Research and Education Networking As Targeted by eEurope, http://www.serenate.org/publications/d6-serenate.pdf
APAN: Asia-Paciﬁc Advanced Network

- APAN: Asia-Paciﬁc Advanced Network
- Partner in TransPAC link
- Several national networks moving to 10Gbps
- APAN network made up of country-owned point-to-point links contributed to APAN
- Trans Eurasia and Trans Paciﬁc connectivity increasing
• The latest fiber now will connect South Asia with South East Asia RENs.
• Connections APAN to US
  • Currently 2xOC12 Tokyo – Seattle, Tokyo - Chicago
  • Upgrading to 2.5Gbps Tokyo – Los Angeles and 2x1GbE Tokyo - Chicago
  • Funded by NSF and Japanese government

SRC: http://www.transpac.org
During last 3 years, several firms have been building optical fiber rings in LA&C

- Significant projects underway

- Opening exciting and new possibilities for cooperation in advanced technological and scientific applications

**Latin America**

- **Panamerican**
- **Global Crossing & Emergia**
- **ImpSat**
- **Transandino**
- **UniSur**
- **Global Crossing**
Africa

- No dedicated R&E network connectivity from African continent
- Some national inter-university connections:
  - South Africa: Tertiary Education Network (TENET)  
    [http://www.tenet.ac.za/](http://www.tenet.ac.za/)
  - Egypt: Egyptian Universities Network (EUN)  
    [http://www.frcu.eun.eg/](http://www.frcu.eun.eg/)
  - Morocco: Maroc Wide Area Network (MARWAN)  
    [http://www.marwan.ac.ma/](http://www.marwan.ac.ma/)

National Institutes of Health MIMcom project

- Satellite connectivity to malaria research sites in Ghana, Kenya, Tanzania  
Global REN Services & Applications

GRENs will spearhead a new generation of advanced applications and services.
Grand Digital Libraries

- Grand projects are now underway to digitize all available books that mankind possess. Some estimate as much as 10 million books will be soon freely available on our desktops in few years.

- Some of the most valuable resources used to be available only to the limited scholars in the developed world. But now one can ‘scroll’ the intricate details of original *Diamond Sutra*—which its original printer Wang Jie “reverently made for universal free distribution on behalf of his two parents” in 868 AD, or literally ‘turn’ the pages of *Sultan Bayber’s magnificent Quran* (digital library of British Library, 2005). Materials now can be made universally available irrespective of constraints of time and distance.

The library connects us with the insight and knowledge, painfully extracted from Nature, of the greatest minds that ever were, with the best teachers, drawn from the entire planet and from all our history, to instruct us without tiring, and to inspire us to make our own contribution to the collective knowledge of the human species. I think the health of our civilization, the depth of our awareness about the underpinnings of our culture and our concern for the future can all be tested by how well we support our libraries.

—Cosmos
Carl SAGAN
A copy of the **Diamond Sutra**, found sealed in a cave in China in the early 20th century, is the oldest known printed book, with a date of 868.[1]

“Buddha has finished his daily walk with the monks to gather offerings of food and sits down to rest. One of the more senior monks, Subhuti, comes forth and asks the Buddha a question.

What proceeds from there is a lengthy dialogue. The Buddha is trying to help Subhuti **unlearn** his preconceived, and limited, notions of what reality is, the nature of Enlightenment, and compassion.
Some of the publishers are very large organizations. A federated approach provides higher education community leverage to negotiate better rates for contents.

Avoid paying duplicate subscription for the same journals by multiple institutions.

The REN provides fast access to the vast amount of digital education resources which are available worldwide— but can not be accessed otherwise.

Information property is fast becoming a major commodity in 21st century. Communities need to maintain indigenous expertise to safeguard its financial and strategic rights and interests in this new world. National digital library will help in nurturing this safeguard.
Digital Library Consortium Models

- Developed World/ USA & Europe
  - Initiated by States. (OhioLINK USA)
  - Major libraries are building electronic confederations from state sponsorship, to save and expand into new service.

- Developing World/ INDIA, Pakistan
  - Initiated by UGC/HEC
  - Only opportunity to reduce digital divide.
  - Huge capital saving initiative when most countries are facing rapid expansion of costly higher education need.
## Digital Divide [1]

<table>
<thead>
<tr>
<th>Institution</th>
<th>Books</th>
<th>Serials</th>
<th>DL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jauharlal Nehru University, India</td>
<td>500,000</td>
<td>800</td>
<td>Yes</td>
</tr>
<tr>
<td>Bombay University, India</td>
<td>700,000</td>
<td>n/a</td>
<td>Yes</td>
</tr>
<tr>
<td>Chepauk Library, Madras University, India</td>
<td>509,263</td>
<td>642</td>
<td>Yes</td>
</tr>
<tr>
<td>Calcutta University, India</td>
<td>800,000</td>
<td>795</td>
<td>Yes</td>
</tr>
<tr>
<td>Punjab University, Pakistan</td>
<td>442,300</td>
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<td>LUMS, Pakistan</td>
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<td>325</td>
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<tr>
<td>Quaid-i-Azam University, Pakistan</td>
<td>195,000</td>
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<tr>
<td>University of Colombo, Sri Lanka</td>
<td>400,000</td>
<td>970</td>
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<td>Tribhuvan University, Nepal</td>
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<td>n/a</td>
<td>No</td>
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<tr>
<td>Royal University of Bhutan</td>
<td>n/a</td>
<td>n/a</td>
<td>No</td>
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<tr>
<td>University of Malaya Library, Malaysia</td>
<td>1,239,749</td>
<td>3631</td>
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<tr>
<td>Maldives has no University</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Dhaka University, Bangladesh</td>
<td>550,000</td>
<td>250</td>
<td>No</td>
</tr>
</tbody>
</table>
Enabling Applications

Multi-National GRID Computing: Supercomputing for the Poor
• Connect the Supercomputers (and all other computing resources) on RENs!
Expected Evolution of Grid

Cluster “Grids:
• Job scheduling and queueing on top of cluster servers

Enterprise and Interdepartmental Grids
• Interdepartmental authentication policy, security, accounting.
• Additional features like load balancing.
• Distributed CPU coordination.

Distributed/Partner Grid
• Distributed enterprise, campus, metro environment
• Introduces inclusion of partner companies.
• Policy management, security, multi-site load balancing
• Increased CPU sensitivity to network latency.

Country/Wide Area Service Grids
• Grid service infrastructure
• Issues below on a regional, national and global scale.
Grid Application in RENs

### Table 5.7.1 Disciplines That Are Running Grid-enabled Applications

<table>
<thead>
<tr>
<th>EU/EFTA Countries</th>
<th>NREN</th>
<th>High-energy Physics</th>
<th>Other Physics</th>
<th>Computational Chemistry</th>
<th>Other Chemistry</th>
<th>Biomedical</th>
<th>Astrophysics</th>
<th>Earth Science</th>
<th>Climatology</th>
<th>Other Disciplines</th>
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</thead>
<tbody>
<tr>
<td>Austria</td>
<td>ACoNet</td>
<td>now</td>
<td>planned</td>
<td>now</td>
<td>planned</td>
<td>now</td>
<td>planned</td>
<td></td>
<td></td>
<td>Applied Numerical Simulation</td>
</tr>
<tr>
<td>Belgium</td>
<td>BELNET</td>
<td>now</td>
<td>now</td>
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<td>now</td>
<td>now</td>
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<tr>
<td>Cyprus</td>
<td>CyNET</td>
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<td>now</td>
<td>planned</td>
<td>now</td>
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<tr>
<td>Czech Republic</td>
<td>CESNET</td>
<td>now</td>
<td>now</td>
<td>now</td>
<td>planned</td>
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<tr>
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<td>now</td>
<td>now</td>
<td>planned</td>
<td></td>
<td></td>
<td></td>
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<td>Material Science - Now running</td>
</tr>
<tr>
<td>Finland</td>
<td>Funet</td>
<td>now</td>
<td>now</td>
<td>now</td>
<td>planned</td>
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<td>research on grids - supercomputing</td>
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<tr>
<td>Germany</td>
<td>DFN</td>
<td>now</td>
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<td>Greece</td>
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<td>now</td>
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<td>Regional Garch All Virtual Organisation</td>
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<tr>
<td>Hungary</td>
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<tr>
<td>Switzerland</td>
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<td>UKERENA</td>
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<td>now</td>
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</tbody>
</table>

- Currently 71 of EU RENS are running Grid and it will be 100% by next 2 years.
- Not only High Energy Physics, the use is expanding in other areas as well.
Transforming Applications
Digital Audio & Video
Global Campus IP Telephony

- NEXT: NRENs will begin exchanging IP telephony traffic- extending global direct dial and virtual phones; currently IP telephony peering architectures are being defined and operators are not yet ready to support it.

- Now that IP telephony and its protocols are becoming more mature and products more manageable, NRENs are starting to deploy it.

- 50% of the NRENs in the EU/EFTA countries are running an IP telephony deployment, while about 30% of the NRENs in other countries are running one.
Mega Conferencing

Internet2 Digital Videoconferencing Group

- World’s largest videoconference
- Uses H.323 videoconferencing and a system of distributed MCU’s located around the world
- Used in every fall Internet2 meeting
- In April 2007 I2 meeting 14 universities from Pakistan joined in South Asia REN Workshop in DC.

http://www.mega-net.net/megaconference/
Ubiquitous Conferencing: Access Grid

High Throughput Proteomics at SDSC

Mark A. Miller, Ph.D.
Integrative Bioscience Program
San Diego Supercomputer Center
3D Tele-Immersion & Research Interaction

- Brings together geographically distant participants and shared virtual objects
- Tele-immersive recreation of office environment

Advanced Network & Services, Brown University, University of North Carolina, University of Pennsylvania
http://www.cs.unc.edu/Research/stc/office/
Shared Laboratories (Remote Equipment)

- Computerized excavation backhoe
- Remotely operated, used in hazardous situations.
- Quality of Service is Guaranteed

North Carolina State University
Masters & Maestros in Fine Arts
Multi-Campus Unique Performance Events
Improved Medical Training

- High bandwidth human interaction
- Low latency virtual reality
- Reliable access to computational resources
- Secure retrieval of medical images and data

Source: Parvati Dev
Stanford
New Instruments for Astronomy
Undersea Oceanography

Images National Geographic
The Bigger & Broader Picture

Cross Border Education & Degree
Program Transformation
Future of Research & Higher Education

• No university, organization, national or regional body can succeed in isolation.

• Advanced Internet will be the key infrastructure component of an University.

• REN is needed to cope up with the advanced applications and systems being deployed/envisioned by the current world university community. Universities without REN will be increasingly out of touch.

• RENs will enable advanced collaboration between researchers, scholars, research groups in a much more meaningful way across nations breeding new ideas.
Emergence of Networked Society
• Shift from student mobility to program and provider mobility—numbers of students seeking education in foreign countries still increasing, but more emphasis placed on delivering quality academic courses and programs to students in home countries.
COURAGE: Consortium of Universities for Research and Advancement of Graduate Education

- Peer-to-peer institutional mentorship for strengthening of curriculum and special degree programs.
- Multi-campus doctoral degree program working on problems of global relevance.
- Advanced special-topic course pool with faculty/expert teaming.
- Co-operative doctoral supervising by pooling experts from multiple campuses.
- Multinational research grant activity.
- Institutional bridge.
Developing world universities must place strategic high priority on **ICT & networking infrastructure** to connect scholars, scientists, and researchers both internally and internationally to keep its higher education system at-par with the world.

However, ICT itself is not the goal it’s a means to build a world-class technologically capable country.
• Higher Education not only Trade School
  • Don’t be just the laborer but be the leader.
  • Go for the cream.
    • Use ICT to turn higher education system into an “industrial engine”
      to mass produce the top engineers, doctors, high skilled human
      capital for the world.

• Claim Back Lost Leadership in Many Areas
  • Environment?
  • Agriculture?
  • Developmental economics?
  • Digital archives for Islamic treasures?
  • Asia-Pacific bio-diversity archive?
• Use collaboration to harbinger a new wave of vibrant intellectual and cultural revival. Revive ancient cultural and intellectual ties via technology to claim back lost lead.
  • Digital Silk Route?
  • Oldest universities of the world-Taxilla to Nalonda (Pakistan, India, Bangladesh, Nepal, Sri Lanka).
“Knowledge will forever govern ignorance, and a people who mean to be their own governors must arm themselves with the power which knowledge gives.”

— James Madison
Acknowledgements

• Network MAPS provided by the NRENs.

• TERENA, Trans European Research and Education Networking Association, Compendium of NRENs, 2006.


• World Higher Education Database (WHED), The Int. Association of Universities (IAU), 2004.

